



## LINCOLN LABORATORY MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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TECHNOLOGY IN SUPPORT OF NATIONAL SECURITY



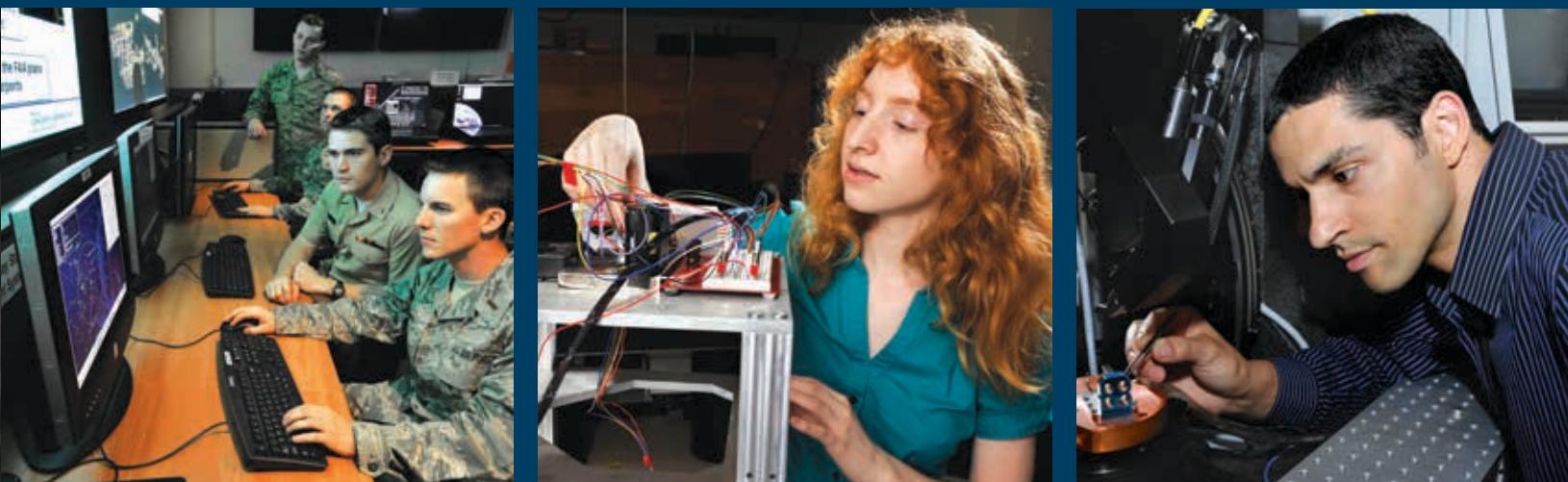
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# MIT LINCOLN LABORATORY

ANNUAL REPORT  
*Technology in Support of National Security*





Massachusetts Institute of Technology



MIT Lincoln Laboratory

## MISSION

# Technology in Support of National Security

MIT Lincoln Laboratory employs some of the nation's best technical talent to support system and technology development for national security needs. Principal core competencies are sensors, information extraction (signal processing and embedded computing), communications, integrated sensing, and decision support. Nearly all of the Lincoln Laboratory efforts are housed at its campus on Hanscom Air Force Base in Massachusetts.

MIT Lincoln Laboratory is designated a Department of Defense (DoD) Federally Funded Research and Development Center (FFRDC) and a DoD Research and Development Laboratory. The Laboratory conducts research and development pertinent to national security on behalf of the military Services, the Office of the Secretary of Defense, the intelligence community, and other government agencies. Projects undertaken by Lincoln Laboratory focus on the development and prototyping of new technologies and capabilities to meet government needs that cannot be met as effectively by the government's existing in-house or contractor resources. Program activities extend from fundamental investigations through design and field testing of prototype systems using new technologies. A strong emphasis is placed on the transition of systems and technology to the private sector. Lincoln Laboratory has been in existence for 60 years. On its 25th and 50th anniversaries, the Laboratory received the Secretary of Defense Medal for Outstanding Public Service in recognition of its distinguished technical innovation and scientific discoveries.

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# MIT and Lincoln Laboratory Leadership

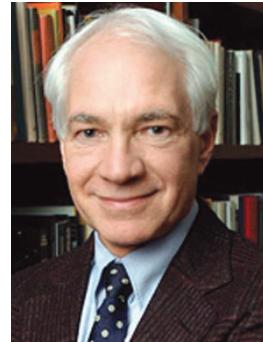
Massachusetts Institute of Technology



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*Vice President*

MIT Lincoln Laboratory



**Dr. Eric D. Evans**  
*Director*

**Dr. Marc D. Bernstein** (standing left)  
*Associate Director*

**Mr. Anthony P. Sharon** (standing right)  
*Assistant Director—Operations*

## Organizational Changes

### Robert G. Atkins

*Division Head, Advanced Technology*



Dr. Robert G. Atkins was appointed to lead the Advanced Technology Division, which conducts research and development of new device concepts and their integration into systems. The division's work spans a wide range of research areas, including high-performance detectors and focal planes, 3D integrated circuits, microelectromechanical devices, diode lasers and photonic devices using compound semiconductors and silicon-based technologies, and high-power fiber and cryogenic lasers. Dr. Atkins, who joined the Laboratory as a technical staff member in 1993, has served in various leadership roles, most recently as the Associate Division Head in the ISR and Tactical Systems Division.

### Simon Verghese

*Assistant Division Head, Advanced Technology*



Dr. Simon Verghese was named Assistant Division Head in the Advanced Technology Division. He joined Lincoln Laboratory in 1995 and has been very involved in the advancement of avalanche photodiode technology. Previously, he served as Assistant and Associate Group Leader of the Laboratory's Electro-Optical Materials and Devices Group. Dr. Verghese assumed his responsibilities as Assistant Division Head on 1 November 2012, after returning from a leadership role in an MIT spin-off company.

### MIT Lincoln Laboratory Fellows

The Fellow position recognizes the Laboratory's strongest technical talent for their outstanding contributions over many years.

### Don M. Boroson



Dr. Don M. Boroson has had key roles in many Laboratory programs in satellite and optical communications. His innovations in laser communications (lasercom) technology, now widely used by the lasercom community, include photon counting, powerful coding, and interleaving techniques. He served as leader of the Optical Communications Technology Group and has led the NASA-sponsored Lunar Laser Communication Demonstration. He has authored dozens of conference papers and journal articles, holds two patents based on his Laboratory work, and is a Fellow of SPIE. He was awarded the 2007 MIT Lincoln Laboratory Technical Excellence Award.

### David C. Shaver

*Deputy Director, Microsystems Technology Office, DARPA*



Dr. David C. Shaver, former Division Head of the Advanced Technology Division, is serving an Intergovernmental Personnel Act (IPA) assignment as deputy director of the Microsystems Technology Office at the Defense Advanced Research Projects Agency (DARPA). During the 18 years he led the division, he directed the Laboratory's pioneering development and demonstration of 193 nm optical lithography technology and developed key programs in photon-counting technology, advanced focal planes, silicon microelectronics, and trusted electronics.

### Deborah A. Valley

*Head; Safety, Mission Assurance, and Program Support Office*



Deborah A. Valley joined Lincoln Laboratory in 2010 as the Head of the Program Support Office. Since then, she has helped execute Level 1 programs, and her leadership has resulted in multiple improvements across the Laboratory. Ms. Valley, who has extensive experience in program management and mission assurance, assumed the new role of Head of the Safety, Mission Assurance, and Program Support Office in May 2012.

### Barry E. Burke



Dr. Barry E. Burke has made significant contributions to the field of electronic imaging. His innovative work in charge-coupled device (CCD) technology has been critically important to many Laboratory programs that required unique, large CCDs. He helped develop the revolutionary orthogonal-transfer CCD array that is enabling the Panoramic Survey Telescope and Rapid Response System's (Pan-STARRS) focal plane, the world's largest focal plane. He has written more than 100 papers and presentations, has been granted 16 patents, has 1 patent pending, and is a Fellow of the IEEE. In 2001, he was honored with a first MIT Lincoln Laboratory Technical Excellence Award.

# Letter from the Director

The challenge MIT Lincoln Laboratory has met since the development of the Semi-Automatic Ground Environment (SAGE) system in the 1950s is the ongoing development of technology in support of national security. We have met this challenge even as the national security landscape changed due to the continually evolving geopolitical environment and rapidly advancing technology. Our success comes in part through a strategy of identifying important new problems well-matched to the Laboratory's expertise, analyzing candidate solutions, and developing and demonstrating technology prototypes. To sustain its relevance to the nation, the Laboratory is strengthening its core mission areas and investing in new research and development directions. New mission areas in cyber security, advanced intelligence, surveillance, and reconnaissance (ISR) technology, and homeland protection directly couple to new national security needs. New initiatives in biomedical research, energy, and autonomous systems are also growing in our portfolio.

In 2012, Lincoln Laboratory had a good year with technology development work in the following areas:

- For advanced over-the-horizon radar systems, the Laboratory developed new signal processing techniques to mitigate clutter and ionospheric propagation issues and demonstrated a next generation of fully digital array architectures.
- Researchers developed a self-contained, cryptographic, field-programmable gate array processor that can be integrated into a variety of hardware systems to secure their data and communications.
- Operational deployment is planned for three wide-area imaging systems: Multi-aperture Sparse Imager Video System (MASIVS); Wide-area Infrared System for Persistent 360° Surveillance (WISP-360); and Imaging System for Immersive Surveillance (ISIS). All three systems use processing and exploitation tools that provide stitching, compression, geostabilization, target tracking, multi-intelligence fusion, and visualization.
- The Laboratory developed and supported quick-reaction counterterrorism capabilities, including novel ground-penetrating radar, a unique robot-mounted sensor system, and two innovative airborne sensors.
- Record performance has been achieved with 1  $\mu\text{m}$  wavelength slab-coupled optical waveguide lasers and amplifiers.

- The Laboratory developed video-analytics technology for performing attribute-based search and for tracking suspects across arrays of conventional security cameras.
- As a key contributor to the Federal Aviation Administration's (FAA) next-generation airborne collision avoidance system, the Laboratory researched an alerting logic that will reduce the frequency of nuisance alerts by 50% while improving safety over the current Traffic Alert and Collision Avoidance System.

The Laboratory's science, technology, engineering, and math (STEM) educational outreach program remains strong. Our Science on Saturday demonstrations are very well attended, and technical staff members reach 7000 students each year through classroom presentations. Our robotics program supports more than 15 teams that participate in For Inspiration and Recognition of Science and Technology (FIRST) competitions. In 2012, the team coached by Laboratory employees competed in the national championship round of CyberPatriot, a high-school cyber defense competition. Also in 2012, the Laboratory held its first summer enrichment program: a two-week "summer camp" experience that teaches science and engineering principles through the construction of small radar systems. These programs are an integral part of our mission.

This annual report highlights many of our past year's accomplishments. We encourage you to review the report to learn more about the Laboratory's technical milestones and community involvement. We look forward to our future achievements, enabled, as they have always been, by our focus on technical excellence, integrity, and innovation.

Sincerely,



Eric D. Evans  
Director

# Lincoln Laboratory Strategic Directions

The strategic directions below are based on a Director's Office and senior management update of the Laboratory's strategic plan and a review of national-level studies, such as the National Defense Strategy, the Quadrennial Defense Review, and recent Defense Science Board recommendations.

- Identify new mission areas, based on current and emerging national security needs
- Strengthen and evolve the current Laboratory mission areas
- Strengthen the core technology programs
- Increase MIT campus/Lincoln Laboratory collaboration
- Strengthen technology transfer to acquisition and user communities
- Increase outside connectivity and communications
- Improve Laboratory diversity and inclusion
- Expand community outreach and education
- Continue improving Laboratory administration and infrastructure







## TECHNOLOGY INVESTMENTS AND TRANSFER

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# Technology Office

*Lincoln Laboratory invests in the development of advanced technologies and capabilities to support the strategic needs of its missions and to promote research in emerging technology areas of relevance to national security.*

The Technology Office is responsible for developing and directing strategic research at the Laboratory through focused investments in existing and emerging mission areas. Members of the office interact regularly with the Assistant Secretary of Defense for Research and Engineering (ASD[R&E]), Defense Advanced Research Projects Agency, Department of Homeland Security, and other government agencies to maintain awareness of the critical problems that threaten national security and to grow strategic technical relationships. The office also collaborates with and supports university researchers and, in doing so, aids in the translation of new technologies from laboratory scale to end-user needs. The Technology Office manages the Laboratory's internal research and development (R&D) investment portfolio through a number of mechanisms, including competitive solicitations, open calls for proposals in specific technical areas, focused infrastructure investments, and activities designed to promote innovative thinking and creative problem solving.

## R&D Investment Portfolio

Internal research funding at Lincoln Laboratory primarily derives from Congressional appropriations administered by ASD(R&E). Additional funding is also available to support laboratory and engineering capability maintenance as well as specific test beds. The Technology Office's investment strategy is focused on ensuring that the Laboratory is appropriately coupled to emerging technology developments, that the Laboratory remains relevant to emerging problems of national security, and that adequate resources and technical infrastructure exist so that the Laboratory can advance into appropriate new technology and mission areas. The internal R&D investment portfolio reflects this strategy, supporting investments in technical infrastructure, basic and applied research, technology development for current Laboratory mission areas, and research thrusts that address emerging national security challenges.



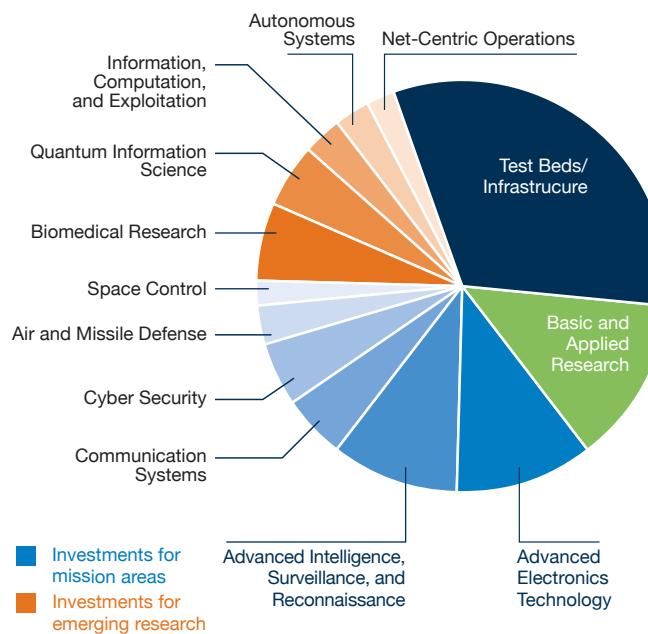
### LEADERSHIP

Dr. Bernadette Johnson, Chief Technology Officer

Dr. Andy Vidan, Associate Technology Officer (left)

Dr. William Herzog, Associate Technology Officer (right)

### INTERNAL R&D FUNDING



## » INVESTMENTS IN TECHNOLOGY DEVELOPMENT FOR MISSION AREAS

### Advanced Technology

Continuing work on the highly successful Geiger-mode avalanche photodiode detector arrays includes research focused on extending their wavelength response beyond 1.6 microns. The new devices will use absorbing regions composed of quantum dots to extend the response of the indium phosphide (InP) material system beyond its traditional range.

In the area of laser sources, the Laboratory is developing an approach to improve the utility of its high-power, slab-coupled optical waveguide lasers (SCOWL) for directed energy applications. Coherent and wavelength beam-combining provide a means to combine 100s or 1000s of laser elements into directed energy lasers. One impediment to beam-combining arrays of semiconductor laser bars is the alignment tolerances required to achieve diffraction-limited performance. This year's SCOWL program seeks to eliminate the need for mechanical alignment by lithographically defining arrays of SCOWL lasers that emit through the substrate.

### Air and Missile Defense Technology

Lincoln Laboratory is researching sensor architectures that combine two-dimensional digital beamforming array antennas with advanced signal processing techniques, such as nonlinear equalization signal processing and time-varying quantization technology. These technologies offer greater sensitivity and clutter rejection. The core technologies to implement this approach can ultimately be integrated into single-chip solutions with greatly reduced size, weight, and power.

### Cyber Security

New cyber security projects include the implementation of cryptographic access control to data to partially enable cloud-based computing and a pilot program to develop a cyber situational awareness system. Using the Laboratory's network as a test bed, researchers are developing and deploying software tools for investigating system compromises, assessing damage and identifying compromised systems, and recommending courses of action to restore functionality.

### Communication Systems

Superconducting nanowire detectors enable very-long-baseline, high-bandwidth, free-space optical communications. Currently, Laboratory researchers are developing improved optical cavities that permit larger active-area devices with high yield, high efficiency, and high speed. Larger active areas are important

to many applications that do not have single-mode optical sources, including light that has been scattered or distorted by atmospheric effects. Additionally, the development of free-space optical coupling and large detector arrays may lead to new applications in imaging, spectroscopic measurements, lower-loss coupling to free-space optical beams, and coupling to fiber arrays or bundles.

### Intelligence, Surveillance, and Reconnaissance Systems and Technology

Building on the successful demonstration of a 120 GHz bandwidth, optical, inverse synthetic aperture lidar, the Laboratory is working to develop a variant of the technology that dramatically improves the coherent integration time and link budget. Other technology developments for active optical systems include an in-pixel signal processing specially tailored for coherent lidar imaging applications and a third generation of functionalized optical transceivers for remote detection.

*Continues on page 10 >>*



Al Ruff is operating a flip-chip bonding tool that is used to align and attach Geiger-mode avalanche photodiodes (APD) to readout integrated circuits (ROIC). An example of a dual 128 x 32 APD/ROIC integrated module is shown left.

>> *Technology Office, cont.*

## » INVESTMENTS IN EMERGING RESEARCH

### Net-Centric Operations

Net-centric approaches to information discovery, sharing, and understanding are key enablers for agile mission execution across the Department of Defense (DoD) and other government agencies. Loose coupling and compositability are characteristics that will allow government systems to respond to needs and missions that were not anticipated when the systems were designed. Formal semantic descriptions embodied in semantic web ontologies are needed to fully realize the DoD's net-centric vision for enterprise and

tactical-edge applications. Currently, the net-centric operations initiative is focused on the following research.

- Research is being conducted on protocols and control structures for net-centric operation in tactical-edge systems that are subject to challenging communication environments.
- Approaches to cyber situation awareness and command-and-control systems include semantic representation and machine processing of trust, provenance, and pedigree for data.

### *in focus // EMERGING RESEARCH*

## Autonomous Systems

The Laboratory's applied research and development are enabling unmanned systems that require infrequent human intervention to perform complex tasks in unstructured, dynamic, and uncertain environments. The Laboratory is also investigating new autonomy-enabled capabilities and is seeking to amplify the effectiveness and efficiency of human operators, analysts, and teammates interacting with unmanned systems. Research is ongoing in the areas of perception, planning, actuation, machine learning, state estimation, world modeling,

multiagent coordination, and human-machine collaboration.

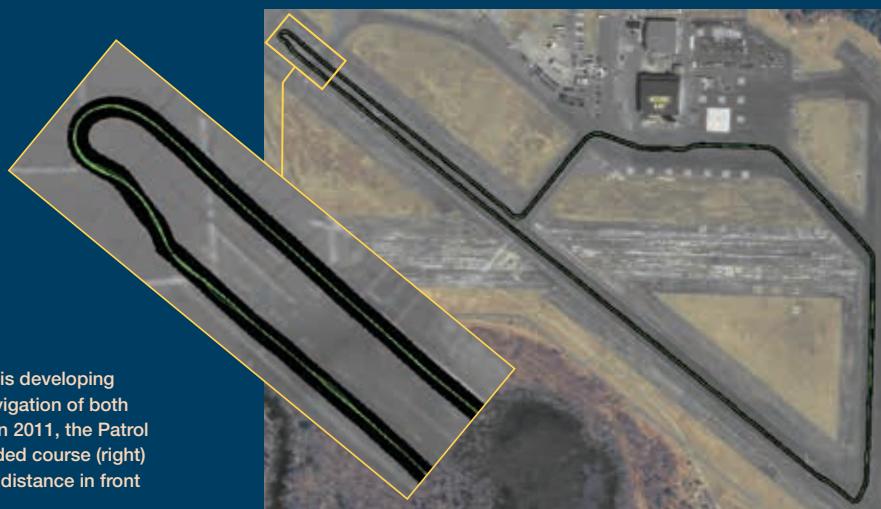
The autonomous systems initiative leverages the Laboratory's associations with research universities and its traditional strengths in control systems, sensing, data fusion, and system-based design to transfer promising algorithms and technologies from academia into mission-relevant prototypes. For example, technologies developed as part of a prior indoor mapping effort have since been incorporated into a DoD-sponsored

program employing unmanned systems to reduce risks to warfighters performing sensitive site assessment of chemically contaminated areas.

Currently, the Laboratory is addressing the challenges of providing robust performance in complex, real-world environments; sharing information and reasoning among heterogeneous autonomous agents; and developing trust and understanding between autonomous systems and humans.



The Outdoor Unmanned Ground Vehicle Navigation program is developing algorithms and infrastructure to enable robust unmanned navigation of both structured and unstructured (e.g., woodland) environments. In 2011, the Patrol Leader platform (above), autonomously traversed a prerecorded course (right) at Moore Army Airfield while maintaining a constant standoff distance in front of a human-occupied vehicle.



- Services for knowledge creation are being developed to address performance bottlenecks and assist analysts in aggregating, visualizing, and interpreting massive heterogeneous datasets.
- Algorithms are being developed for service composition and automated resource brokering based on formal semantic descriptions. Technical areas to be addressed are distributed planning and execution by collaborating software agents, user preferences in data discovery/sharing/understanding, and semantic representations.

### Information, Computation, and Exploitation

The Laboratory is advancing innovation in data processing, computation, exploitation, and visualization through applied research and development in several key areas: analytics and exploitation, processing and architectures, extreme computing, and data delivery. A long-term objective is to develop a data-intensive, cloud analytics infrastructure at the Laboratory to enable collection, fusion, and exploitation of structured and unstructured datasets. The current emphasis is on full-motion video analytics, graph analytics, multisensor fusion, and open-source data exploitation.

*Continues on page 12 >>*

## Biomedical Research

Biomedical research is a new field of exploration for Lincoln Laboratory. A 2009 study conducted internally with input from a panel of prominent advisors in the life sciences recommended that Lincoln Laboratory apply its competencies in advanced signal and image processing, electronics and optics, complex system analysis, and biological defense to critical biomedical problems. In response, the Laboratory has committed resources to developing advanced biomedical technologies and systems to address national health-care needs and enhance warfighter performance and resilience.

Specific projects range from novel blood-loss sensors based on the Laboratory's ultra-low power electronics and biosignal processing algorithms, to genome-scale engineering with custom DNA sequences in bacteria. Devices with nanometer and micrometer features take advantage of scaling phenomena via nanopores for screening of genetic modifications and nanoplasmionic arrays for rapid infrared biochemical imaging.

### Synthetic Biology and Genetic Engineering Program

The synthetic biology program within the biomedical initiative seeks to expand the

reach of genetic engineering, from its focus on single genes to complex genetic systems and even to the scale of entire genomes. This research requires a new mindset on how living organisms can be redesigned—and new tools to build, implement, and test those designs toward common goals: producing advanced tools for prototyping designed genetic systems and developing genetic control features for new degrees of biosafety and biosecurity.

The synthetic biology program built microfluidic DNA assemblies, produced the first publication leading to a reengineered genetic code (with MIT and Harvard collaborators), and performed microfluidic transformation of cells with DNA. Researchers are characterizing *rE. coli* 1.0, the first organism with a genome rewritten to alter its genetic code, demonstrating a new, robust type of microbial control system. The Laboratory is also currently producing microfluidic platforms for DNA assembly/ transformation and gene synthesis from microarrays.

### Nanopore Program

Lincoln Laboratory has been involved in the design, development, and testing of integrated solid-state nanopore devices in



Lincoln Laboratory researcher David Kong develops microfluidic technology for rapid prototyping in synthetic biology.

collaboration with Professor Rohit Karnik at MIT. The unique devices are robust and will find use in a number of critical applications from DNA profiling for forensics, epigenetic screening, synthetic biology, RNA detection, and eventually single-molecule sequencing. This program exploits the Laboratory's strengths in nanofabrication, sensor development, signal processing, and bioinformatics.

>> *Technology Office, cont.*

- Video analysis tools are being developed for wide-area video sensor data from outdoor border environments. These tools include ones for detection of human or vehicle motion and identification of their activities, for pattern-of-life analyses of observed motion and activity to detect deviations from typical activity, and for video-content summarization to condense large amounts of sparse video data into short segments.
- Detection theory for graph-valued data is focusing on the detection of small, topologically distinct subgraphs in a large, noisy, dynamic background.
- The Laboratory is investigating automated approaches for fusing images and video to underlying 3D geospatial models and for constructing network associations between entities in the underlying images.
- To exploit the extensive and timely open sources of information available on the Internet, researchers are prototyping and deploying novel semantic analytics tailored to Internet data sources.

## *in focus // EMERGING RESEARCH, CONT.*

### Quantum Information Science

Quantum information science (QIS) is a fundamentally different and, for certain classes of problems, exponentially more powerful way to process information. The Laboratory's work in QIS is focused on developing the fundamental building blocks for quantum information processing in a manner that is readily scaled up to larger-scale demonstrations. Currently, work is focused in three areas: superconducting quantum bits (qubits), trapped ion qubits, and quantum photonic technologies.

**Superconducting Quantum Bits (qubits)**  
Superconducting qubits can be designed and fabricated with many of the same tools used for conventional semiconductor integrated circuits. However, imperfections of the materials and fabrication techniques introduce mechanisms that make the lifetimes of the needed coherent quantum mechanical state short-lived (10s of  $\mu$ s). The Laboratory is working to identify materials and fabrication techniques that minimize these imperfections and to develop qubit designs that are robust to the imperfections that cannot be removed.

#### Trapped Ion Qubits

Trapped-ion qubits, based on the manipulation of a quantum mechanical

state of an electron, have the advantage of relatively long coherence times of a second or more. The disadvantage is that the path to a larger-scale demonstration has more challenges than other qubit modalities. The Laboratory is addressing two of the most significant challenges. The first is the development of a technique to quickly fill and replenish ions in the trap. The Laboratory's unusual approach creates a magneto-optical trap (MOT) to hold a reservoir of neutral atoms. A laser pushes these atoms from the MOT reservoir to the trap where they are ionized with a second laser and held in the trap by an electromagnetic field. The second challenge is the reduction of the size of the trap to permit faster qubit manipulation times.

#### Quantum Photonic Technologies

The Laboratory's work in quantum photonic technologies is focused on developing resources that can be applied to a broad range of applications such as verifiably secure communications, quantum key distribution, and verifiable random number generation. Common requirements of these applications are the ability to generate entangled photon pairs and the ability to detect a single photon, both at high rates. In collaboration with MIT



Dilution refrigerator for experiments on superconducting qubits.

campus, the Laboratory is developing an entangled photon source capable of generating more than 1 million photons per second. Researchers are also working to develop single-photon detectors with > 95% efficiency through the use of low-temperature superconducting films.

## » LABORATORY TECHNICAL CHALLENGES

The Technical Challenges are internal exercises that enable multi-disciplinary teams to work on innovative solutions to difficult but highly relevant national security problems. Representatives from the Laboratory's mission areas identify appropriate problems and then formulate competitive challenges to address them. After a competitive proposal process, finalists are chosen and given three to six months to research, develop, test, and evaluate

their projects. The finalists demonstrate their solutions and then present their results to the Laboratory community. These challenges have had significant technical impact, as teams have shared their research at technical conferences. Past challenges that focused on unmanned surveillance, data analysis, and novel materials applications elicited diverse, novel solutions.

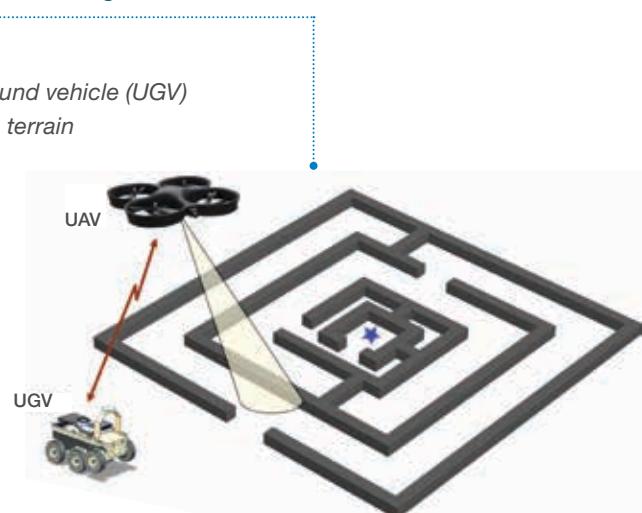
### 2012 Unmanned Air and Ground Vehicle Autonomous Maze Traversal Challenge

#### GOAL

*Demonstrate cooperative unmanned air vehicle (UAV) or unmanned ground vehicle (UGV) operation that will enable unmanned ground traversal through unknown terrain*

#### SAMPLE SOLUTIONS

- System utilizing a combination of a long-endurance, lighter-than-air aerial vehicle with a single tracked ground vehicle, both sensor-equipped and linked together with a triple-redundant RF communications system
- System using two ground vehicles to cooperatively navigate a maze with the assistance of two aerial vehicles
- System employing unmanned ground vehicles that receive assistance from close-in hexacopters and an overhead persistent-surveillance blimp



### 2011 Metamaterials—Build-It!

#### GOAL

*Design, develop, and demonstrate a novel metamaterial application*



#### APPLICATIONS

- Metamaterial radar absorber for VHF/UHF stepped-frequency ground-penetrating radar antenna array
- Fingerprint imaging with ultrasonic acoustic metamaterials
- Novel microwave absorber utilizing broadband volumetric metamaterials
- Rebuilding the Lüneburg lens for mobile field-deployable satellite communications

### 2011 Data Exploitation Challenge

#### GOAL

*Develop new algorithms and techniques to exploit 3D ladar imagery.*



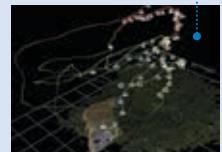
#### SOLUTIONS

- Multiple-intelligence fusion demonstrations, combining high-resolution ladar data, ground moving target indication simulations, and ground-based infrared video
- Algorithms spanning classification, terrain analysis, path optimization, tactical guidance, and visualization to aid mission planning
- Geographic query system that preprocesses and indexes ladar, geographic information system, and other data to provide efficient constraint- and exemplar-based querying capability

### 2010 Rapid Surveillance Challenge

#### GOAL

*Obtain complete situational awareness of activities within a 1 km<sup>2</sup> area with no prior knowledge of site and no human incursion into the area*



#### SOLUTIONS

- Cooperative network of ground and aerial vehicles, including networked sensor motes dropped from an aerial platform, combined with advanced networking and analyses
- Multilayered system including a combination of fixed and mobile air and ground-based platforms, and advanced image processing techniques

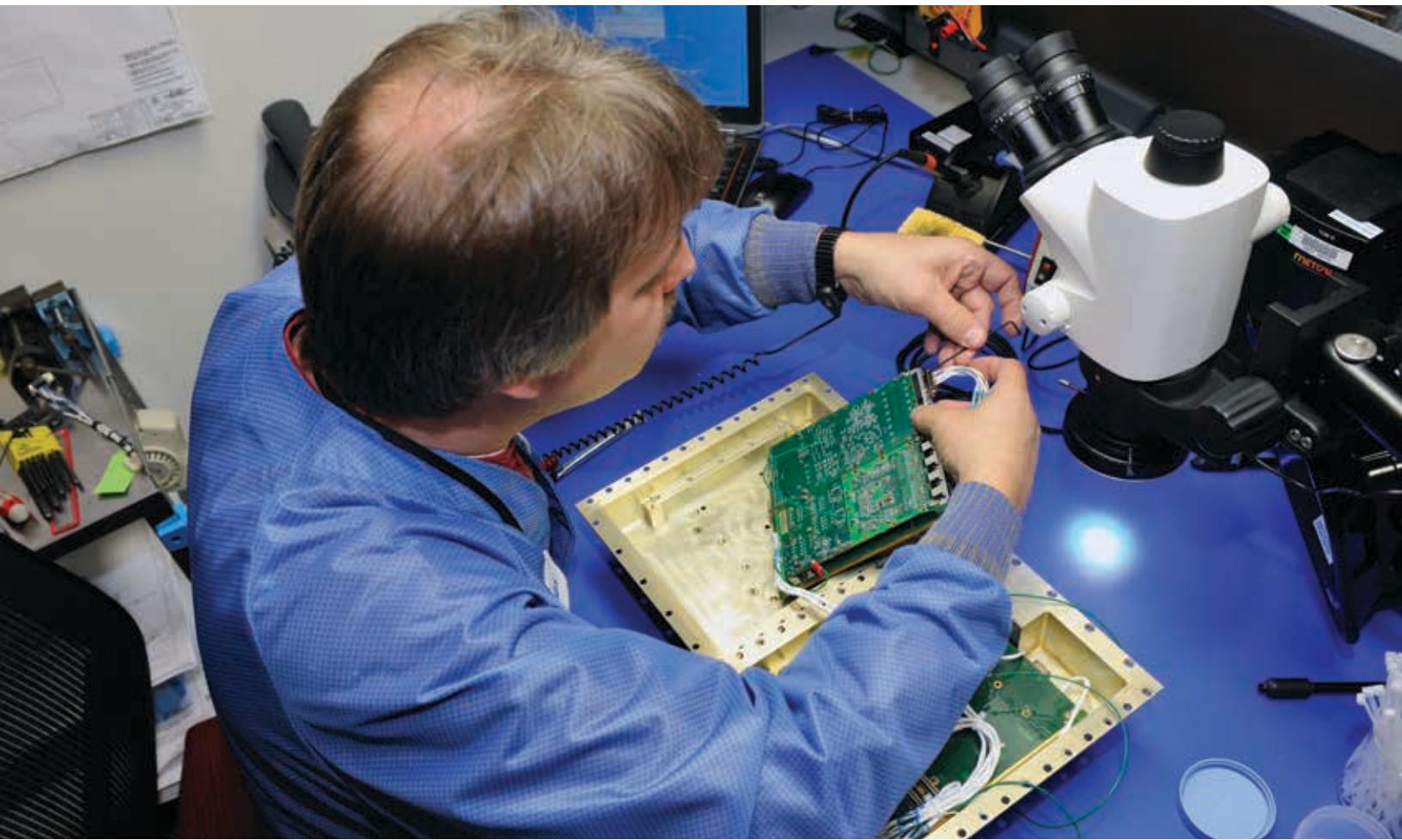


## New Rapid Hardware Integration Facility

Lincoln Laboratory's new 3900-square-foot engineering facility supports the rapid integration and fielding of specialized systems for the Department of Defense, the Department of Homeland Security, and other Laboratory sponsors. This purpose-built facility was designed to accommodate an increased emphasis on rapid prototyping efforts. Over the past five to six years, the Laboratory established new groups and approaches to facilitate the success of these efforts and to better disseminate lessons learned. The remodeled facility complements these changes by providing the appropriate tools, collaborative environment, and required infrastructure to sustain rapid prototyping projects.

The facility can accommodate the development of about five to eight systems, all with concept-to-system delivery timelines of less than 12 months. Currently, more than 20 staff members and technicians are working together on seven different prototype efforts that answer a broad range of critical national security needs, including protection of forward operating bases in theater, airborne surveillance, port security, and signals-intelligence problems. The facility is also used to explore new approaches to rapid system development.

ABOVE, CLOCKWISE FROM LEFT: Technicians in the Fabrication Engineering Group take advantage of the collocated tools in the new rapid integration facility: mechanical assembly technician Alan Hamilton tunes robotic arms for a project for the Department of Homeland Security; Thomas Kelley adjusts the optics on an advanced infrared system for base protection; Thomas Grasso, an electronics technician, is inserting and ruggedizing connectors for an electronics board for an unmanned aerial vehicle. Michael Stern, an assistant technical staff member in the Rapid Prototyping Group, builds thermoplastic parts by using a fused deposition modeling production system.



## Facility Features

The rapid prototyping space, spread over two floors, is designed to maximize collaboration between team members and to minimize the time to iterate through the design-build-test cycle. The flexibility to reconfigure the space to adapt to a wide variety of projects was also a key design factor. The facility is divided into areas for system integration, electronic assembly, additive manufacturing (3D printing), and conventional machining. The major features of the facility include

- Space for the collocation of project team members during system integration
- Open space for flexibility during the staging of parts and assembly
- A small machine shop for fast turnaround of modifications to parts
- State-of-the-art 3D “additive” manufacturing tools
- Electronics assembly area to facilitate quick-turnaround changes
- Common area for impromptu team meetings



Machinist Russell Gouveia sets up new billet of aluminum to be machined into a complex part for an aircraft pod program.

# ENERGY

## Overview

Lincoln Laboratory has a rich history of developing energy technology. In its early days, the Laboratory was involved in satellite power systems. Later, during the oil crisis of the 1970s, the Laboratory engaged with the Department of Energy (DoE) to develop and field solar photovoltaic systems. Today, the Department of Defense (DoD) confronts the challenge of maintaining energy security in both field operations and fixed installations despite growing concerns about the sustainability of their traditional energy solutions and practices. Lincoln Laboratory is playing an important role in assisting DoD energy system transformation by providing energy system analysis, modeling, and architecture trade studies, as well as advanced technology development and evaluation in instrumented test beds. This work is focused on advanced microgrid solutions for both installations connected to the national grid and for forward operating bases; hybrid electric vehicle solutions; advanced technology enabling lighter, more efficient solar photovoltaic systems; higher-voltage, gallium nitride power electronics; and efficient soldier-scale capabilities, including solar-powered unmanned aerial vehicles.

## Principal 2012 Thrusts

Lincoln Laboratory is supporting energy efforts for DoD installations through a DoD microgrid study. The study will survey numerous existing and planned microgrid projects, evaluate comparative costs and energy security benefits, and assess the potential for incorporating new technologies to achieve improved cost-effective performance.

An Air Force-sponsored study of fleet vehicle electrification is exploring the trades for different deployment architectures, including a charging infrastructure that captures the full value of grid-connected vehicles, as microgrid resources that can reduce costs, increase stability, and increase energy security.

Lincoln Laboratory is working with MIT campus to advance solar organic photovoltaic (PV) systems to achieve greatly increased weight-efficient performance for operational battery-recharging

systems. This collaboration is also pursuing increased area-efficient performance through a novel spectral splitting and Earth-abundant materials approach to silicon-based PV.

The DoE is sponsoring a joint effort between the Laboratory and MIT to advance gallium nitride materials and devices for high-voltage power electronics. The goal of this work is to enable more efficient power conversion and higher-voltage and higher-frequency power distribution and control.

Working closely with the National Renewable Energy Laboratory and DoD partners at the U.S. Army Kwajalein Atoll and the Space Fence program, the Laboratory is conducting a detailed study into alternative energy solutions, such as wind, solar, and sea water air-conditioning and cooling power, for the Reagan Test Site, which has been selected as an Army Net-Zero Energy Initiative site.

In collaboration with the DoE and DoD, the Laboratory is studying the impact of wind-power deployments on the national radar air picture and is also investigating options and trades to mitigate these impacts in ways that preserve air defense capability and aviation safety and that cost-effectively enable the development of wind-power projects.

The Laboratory is exploring advanced soldier-scale capabilities that must operate on hand-carried battery power or alternative portable sources. These capabilities include advanced sensing and communications systems for unmanned ground systems and, most recently, solar-powered, hand-launched unmanned aerial vehicles.

## Future Outlook

Lincoln Laboratory will continue to support the DoD with energy system analysis and architecture engineering studies, as well as the advancement of integrated microgrid systems and enabling component technologies that can help transform DoD energy systems and improve national energy security.

# X-Band Transportable Radar

The X-band Transportable Radar (XTR-1), developed to support Missile Defense Agency (MDA) testing in the Pacific, was integrated onto MDA's instrumentation ship, the *Pacific Tracker*, in 2010. Following shake-down at-sea testing, the radar system supported two mission deployments, gathering valuable X-band and S-band data. Analyses of mission and at-sea calibration data demonstrated the utility of the system and the achievement of all performance requirements. During the three at-sea deployments, training of the future operations crew was completed.

The XTR-1 system provides high-resolution, high-prf (pulse-repetition frequency), instrumentation-quality radar data in S and X bands. The design utilizes a commercial off-the-shelf antenna, transmitters, and microwave hardware coupled with a Lincoln Laboratory-designed dual-frequency feed. Radar system control and recording is provided by a Radar Open System Architecture (ROSA) design that is a derivative of the ROSA systems at the Reagan Test Site (RTS) on the Kwajalein Atoll, the Pacific Missile Range Facility (PMRF) in Hawaii, and the Lincoln Space Surveillance Complex at Millstone Hill, Westford, Massachusetts.

The XTR-1 radar system was developed to fill a need for instrumentation-quality radar data during testing of the Ballistic Missile Defense System (BMDS). Without the mobile radar coverage provided by a sensor such as XTR-1, MDA was constrained to test only interceptor flight regimes that could be covered by land-based radars at RTS, PMRF, or Vandenberg Air Force Base, California, or to test without adequate diagnostic data. As a result of a Test Infrastructure Study, MDA developed several mobile (ship- and aircraft-based) sensor systems. Efforts to develop the XTR-1 system began in late 2005.

The XTR-1 system was transferred to the Naval Air Systems Command (NAVAIR) Ranges Department at the Naval Air Warfare Center Weapons Division at Point Mugu, California, in summer 2012. Extensive documentation that includes Lincoln Laboratory and vendor documents and drawings has been provided for the crews NAVAIR has contracted to maintain and operate the hardware and to perform mission support. Lincoln Laboratory will continue to assist with real-time software systems and technical issues, including planned improvements over the next several years. The Laboratory will also provide the primary mission planning, data analysis, and performance tracking efforts for MDA.

The XTR-1 system is installed on the stern of the *Pacific Tracker*. The XTR-1's at-sea testing was conducted off the coast of Oregon.



# Economic Impact and Technology Transfer

Lincoln Laboratory's research and development activities strengthen both the nation's technology base and its economy. The continuing development of new capabilities and emerging enabling technologies that are transitioned rapidly to the military services, government agencies, and industry helps ensure not only that advanced technology is available to the U.S. military services and government agencies, but also that U.S. industry is at the forefront of technical innovation.

Technology transfer is accomplished through deliveries of hardware, software, algorithms, or advanced architecture concepts; Small Business Technology Transfer joint research partnerships with local businesses; Cooperative Research and Development Agreements that are privately funded by businesses; and the licensing of MIT patents to companies.

## Economic Impact

During fiscal year 2012, the Laboratory issued subcontracts with a value that exceeded \$437 million. The Laboratory purchased more than \$218 million in goods and services from New England companies, with approximately \$186 million placed locally in Massachusetts. Small businesses—which supply construction, maintenance, fabrication, and professional technical services in addition to commercial equipment and material—are primary beneficiaries of the Laboratory's outside procurement program. In 2012, 52.3% of subcontracts were awarded to small businesses of all types (as reported to the Defense Contract Management Agency). The Laboratory's Small Business Office is committed to an aggressive program designed to afford small business concerns the maximum opportunity to compete for purchase orders.

## Technology Transfer Activities

### Communication Systems

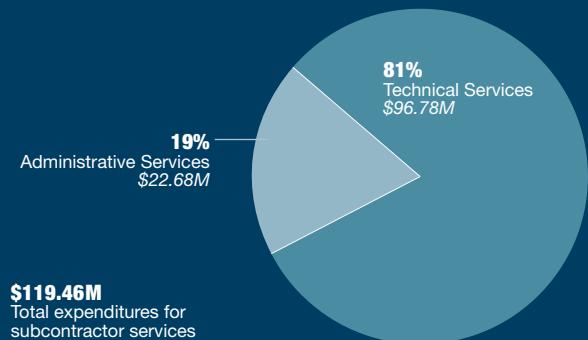
A new system to aid foreign language learners in developing their pronunciation skills was delivered to the Defense Language Institute. The system applies speech recognition technology to produce online assessments of pronunciation so that students can interactively improve their pronunciation.

A high-data-rate waveform for wideband, transponded satellite communications was demonstrated and delivered to more than 15 industry and government organizations.

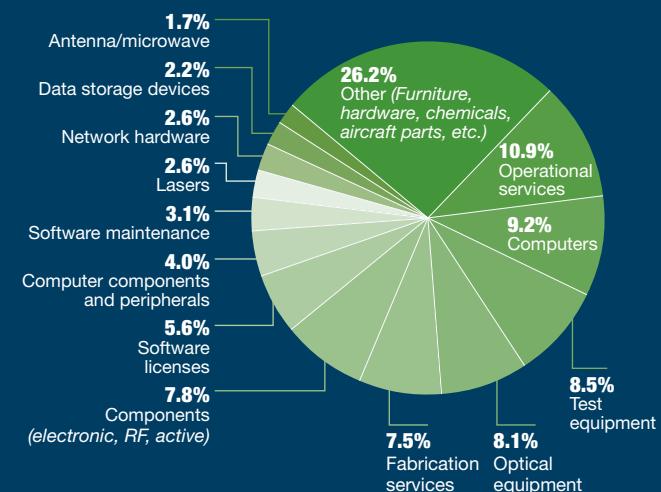
The prototype software for a radio-to-router Common Virtual Multipoint Interface for the Linux operating system was released for public access as open-source code. The interface will simplify interoperability among heterogeneous radios.

## ECONOMIC IMPACTS

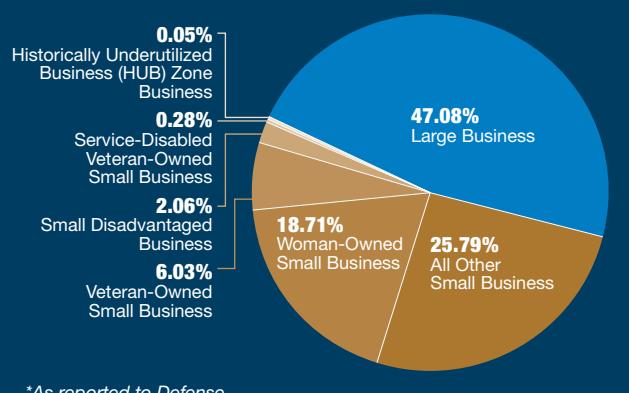
### (a) Subcontractor services (FY 2012)



### (b) Commercial hardware and materials contracted to businesses (FY 2012)



### (c) Contract awards by category of businesses (FY 2012)\*



\*As reported to Defense Contract Management Agency (DCMA)

## Selected Patents

**External-Cavity One-Dimensional Multi-Wavelength Beam Combining of Two-Dimensional Laser Elements**  
*Bien Chann, Tso Yee Fan, and Antonio Sanchez-Rubio*  
U.S. Patent No.: 8,049,966  
Date issued: 1 November 2011

**Apparatus for Isolating a Nucleic Acid from a Sample**  
*Lalitha Parameswaran, James Harper, Johanna Bobrow, Mark A. Hollis, Drew C. Brown, Laura T. Bortolin, Eric S. Clasen, and John C. Schmidt*  
U.S. Patent No.: 8,062,846  
Date issued: 22 November 2011

**Optoelectronic Detection System**  
*Eric D. Schwoebel, James D. Harper, Martha S. Petrovick, Frances E. Nargi, Todd H. Rider, Kristine E. Hogan, Richard H. Mathews, Joseph Lacirignola, Mark Hennessy, Trina R. Vian, Rose M. Joseph, Raymond S. Uttaro, Shaun Berry, Bernadette Johnson, and Mark A. Hollis*  
U.S. Patent No.: 8,067,184  
Date issued: 29 November 2011

**Method and Apparatus for Transmitting Optical Signals**  
*David O. Caplan*  
U.S. Patent No.: 8,073,342  
Date issued: 6 December 2011

**High Fill-Factor Avalanche Photodiode**  
*Matthew J. Renzi, Brian F. Aull, Robert K. Reich, and Bernard B. Kosicki*  
U.S. Patent No.: 8,093,624;  
Date issued: 10 January 2012

**Multi-tone Resist Compositions**  
*Theodore H. Fedynyshyn*  
U.S. Patent No.: 8,110,339  
Date issued: 7 February 2012

**Resist Sensitizer**  
*Theodore H. Fedynyshyn*  
U.S. Patent No.: 8,158,338  
Date issued: 17 April 2012

**Single-Transducer, Three-Dimensional Laser Imaging System and Method**  
*Bryan S. Robinson, Don M. Boroson, and Marius A. Albota*  
U.S. Patent No.: 8,159,680  
Date issued: 17 April 2012

**Asymmetric Multilevel Outphasing Architecture for RF Amplifiers**  
*Joel L. Dawson, David J. Perreault, SungWon Chung, Philip Godoy, and Everest Huang*  
U.S. Patent Nos.: 8,164,384 and 8,026,763  
Dates issued: 24 April 2012 and 27 September 2011

**Digital Readout Method and Apparatus**  
*Michael Kelly, Daniel Mooney, Curtis Colonero, Robert Berger, and Lawrence Candell*  
U.S. Patent No.: 8,179,296  
Date issued: 15 May 2012

**Detection of Materials via Nitrogen Oxide**  
*John J. Zaykowski, Mordechai Rothschild, Charles M. Wynn, and Roderick R. Kunz*  
U.S. Patent No.: 8,198,095  
Date issued: 12 June 2012

**Space-Time Digital Power Amplifier**  
*Joel I. Goodman, Helen H. Kim, Benjamin A. Miller, and James E. Vian*

U.S. Patent No.: 8,204,148  
Date issued: 19 June 2012

**Pathogen Detection Biosensor**  
*Eric Schwoebel, James Harper, Martha Petrovick, Frances Nargi, Mark Hollis, Bernadette Johnson, Joseph Lacirignola, Richard Mathews, Kristine Hogan, Trina Vian, Allan Heff, Mark Hennessy, Sangeeta Palchaudhuri, and Todd Rider*  
U.S. Patent No.: 8,216,797  
Date issued: 10 July 2012

**Phase-Locked Loop Frequency Synthesizer**  
*Helen H. Kim, Matthew D. Cross, Merlin R. Green, and Daniel D. Santiago*  
U.S. Patent No.: 8,242,818  
Date issued: 14 August 2012

**High Duty Cycle Radar with Near/Far Pulse Compression Interference Mitigation**  
*William S. Song*  
U.S. Patent No.: 8,259,003  
Date issued: 4 September 2012

### Cyber Security

Lincoln Laboratory transferred a malware triage system to sponsor organizations. Cyber range technology was provided to government and industry cyber ranges.

### Air Traffic Control

Core components of the Tower Flight Data Manager (TFDM) were transferred to an industry contractor for deployment to Dulles International Airport, Washington, D.C.

The Corridor Integrated Weather System (CIWS) Data Distribution Service (CDDS) is a System-Wide Information Management (SWIM) Segment 1 program, providing high-quality current and 0-2 hr weather-forecast data for airlines and Federal Aviation Administration (FAA) traffic flow management personnel. CDDS became operational in 2012 and is now integrated into the FAA's

Traffic Flow Management automation for use in air traffic control facilities across the United States.

### Intelligence, Surveillance, and Reconnaissance Systems

In support of the national need for wide-area motion imaging, the Laboratory continued to support the Constant Hawk (Army) and Gorgon Stare (Air Force) programs. Onboard processing software improvements, ground station upgrades, and viewer and exploitation tool enhancements were delivered to operational users to improve the efficacy of these systems.

The Airborne Ladar Imaging Research Testbed (ALIRT) system developed by the Laboratory continues its operational use on board a government-furnished aircraft. The Laboratory provides support to sensor operation, onboard processing, and image data exploitation tools.



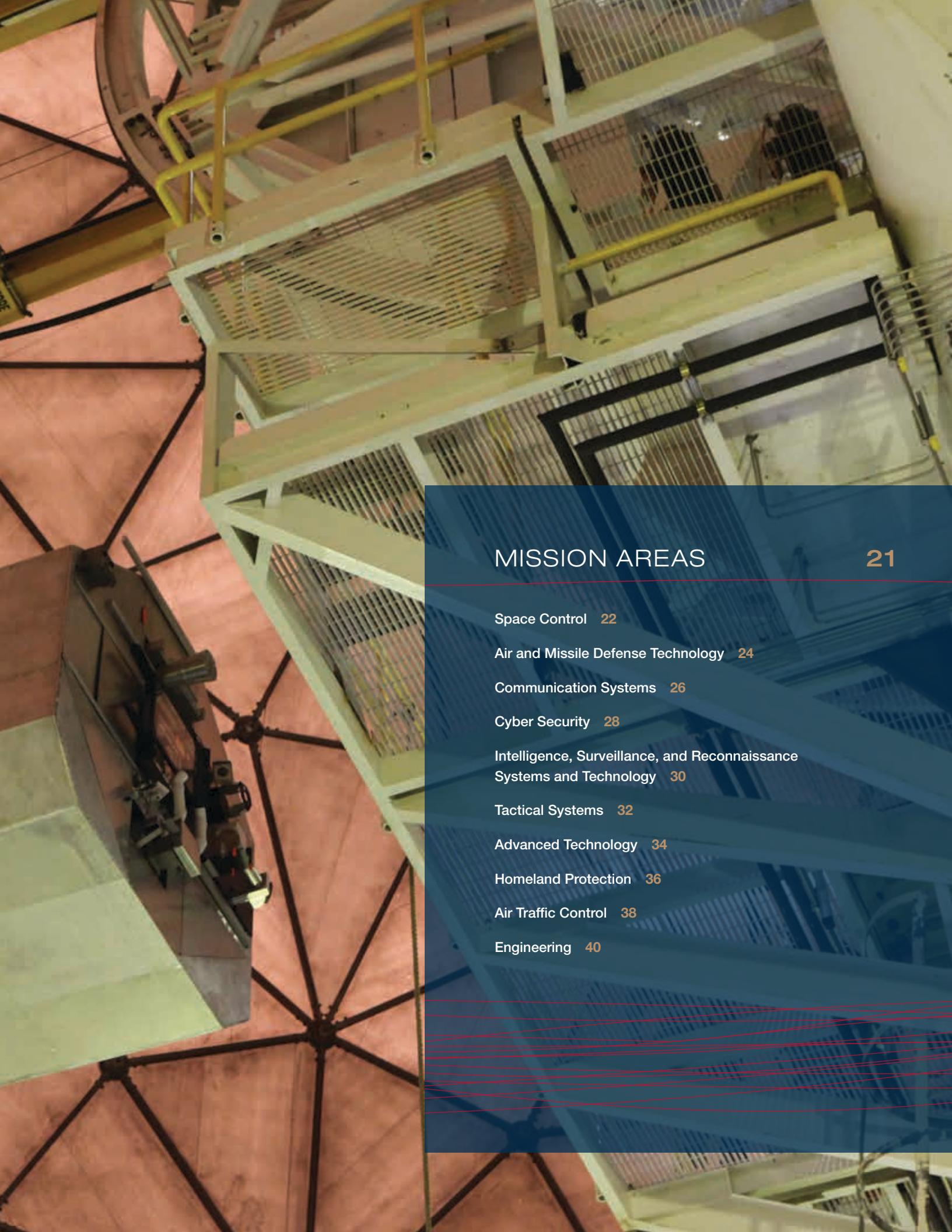
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## MISSION AREAS

21

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Communication Systems 26

Cyber Security 28

Intelligence, Surveillance, and Reconnaissance  
Systems and Technology 30

Tactical Systems 32

Advanced Technology 34

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Engineering 40

# Space Control

Lincoln Laboratory develops technology that enables the nation's space surveillance system to meet the challenges of space situational awareness. The Laboratory works with systems to detect, track, and identify man-made satellites; collects orbital-debris detection data to support space-flight safety; performs satellite mission and payload assessment; and investigates technology to improve monitoring of the space environment, including space weather and atmospheric and ionospheric effects. The technology emphasis is the application of new components and algorithms to enable sensors with greatly enhanced capabilities and to support the development of net-centric processing systems for the nation's Space Surveillance Network.

RIGHT: HUSIR RF box (X-band transmitter and receiver electronics) installation lift.



## Principal 2012 Accomplishments

- The Space Surveillance Telescope (SST), a 3.5 m telescope for searching deep space, is nearing completion of full checkout prior to its inclusion in the U.S. Space Surveillance Network. The SST achieved first light in 2011, and satellite tracking was demonstrated with excellent metric accuracy, sensitivity, and search capability. Several unique capabilities, including autonomous operations and the end-to-end, satellite detection/tracking/correlation data processing pipeline, were also demonstrated during checkout.
- After the X-band transmitter and receiver electronics of the Haystack Ultrawideband Satellite Imaging Radar (HUSIR) were reintegrated, the radar demonstrated successful X-band operation. Antenna-surface refinement, required for W-band operations, is expected to be completed in 2013.
- The Laboratory was selected by the National Space and Aeronautics Administration (NASA) to fly a demonstration sensor package on a CubeSat bus in 2014. The sensor and CubeSat being developed by Lincoln Laboratory and MIT will serve as a pathfinder for future civilian and Department of Defense distributed weather-sensing systems, dramatically reducing cost, schedule, and risk while improving performance and robustness.
- In support of the development of a robust architecture for space situational awareness, Lincoln Laboratory conducted trade studies and investigated opportunities for technology investment and maturation. The studies examined how existing and planned capabilities supporting other mission areas may be leveraged for application to space situational awareness in order to address the budget constraints of the current defense acquisition environment.
- Continuing its history of significant contributions to the nation's environmental monitoring needs, Lincoln Laboratory began assessing the performance of the atmospheric sounding sensor suite on the Joint Polar Satellite System, launched in October 2011. The Laboratory has supported this system since its inception in the 1990s. Performance results to date are exceeding all specifications. Data from this new system may enable novel sounding algorithms, leading to substantial improvements in processing and performance.
- To address the needs of the U.S. space control mission area, a portfolio of efforts is directed toward a comprehensive,

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*Leadership*



Dr. Grant H. Stokes



Mr. Lawrence M. Candell



Mr. Craig E. Perini



MIT students are assembling a CubeSat, that will incorporate a Lincoln Laboratory weather sensor. The CubeSat is intended for launch aboard a NASA space vehicle scheduled for flight in 2014.

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## Future Outlook

net-centric, situational awareness/command-and-control system. Working with the Air Force and the broader space community, the Laboratory achieved a significant milestone in 2012: the first set of fundamental services (sensor data feeds, processing algorithms, and database functions) was developed, integrated, hosted on an initial hardware system, and demonstrated. These services and capabilities are currently running side-by-side with the legacy situational awareness system in the Joint Space Operations Center, and inputs from users will directly impact the development of the next series of services.

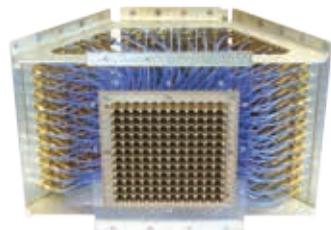
- The Space Surveillance Telescope will complete a Military Utility Assessment, and then will be available to contribute data to the U.S. Space Surveillance Network (SSN).
- The Haystack Ultrawideband Satellite Imaging Radar will complete its checkout and return to its role as an operational sensor in the SSN, operating in X- and W-band modes.
- Lincoln Laboratory will continue efforts to fully utilize data from the existing and planned space surveillance sensors (dedicated and multimission sensors). Transforming these data in a timely manner into information directly usable by the warfighter is a challenge that will be an ongoing thrust of the space control mission.
- Emerging technical areas being pursued include advanced radar developments, radar surveillance, space-object tracking and identification, electro-optical deep-space surveillance, collaborative sensing and identification, data fusion and processing, and information extraction for decision support.

# Air and Missile Defense Technology

Lincoln Laboratory develops and assesses integrated systems for defense against ballistic missiles, cruise missiles, and air vehicles in tactical, regional, and homeland defense applications. Activities include the investigation of system architectures, development of advanced sensor and decision support technologies, development of flight-test hardware, extensive field measurements and data analysis, and the verification and assessment of deployed system capabilities. A strong emphasis is on rapidly prototyping sensor and system concepts and algorithms, and on transferring resulting technologies to government contractors responsible for developing operational systems.



The Camcopter (above) is being considered as a possible UAV platform for an advanced electronic warfare capability for the Navy. The Laboratory is prototyping the electronic attack payload, including an advanced, wideband, scanning, dual-polarized antenna array (inset) and a modular, channelized processing chain.



## Principal 2012 Accomplishments

- A prototype for an airborne infrared processor was integrated with a multi-spectral sensor to demonstrate real-time image processing and data extraction, automatic acquisition, and hands-free closed-loop tracking on the ground. The processing technology was transferred to Raytheon and subsequently flew on a manned airborne platform to track space objects in July 2011 and ballistic missiles in October 2011.
- As Aegis Ballistic Missile Defense (BMD) Advanced Technology Development Agent, Lincoln Laboratory continues to work within the government team to help establish Aegis BMD system requirements and technology needs for future combat systems. Modeling and simulation tools for the Aegis Weapon System and SM3 Missile interceptors are applied to quantify defended area, launch area denied, and raid-handling capacity.
- The XTR-1 mobile instrumentation radar, designed and built by Lincoln Laboratory, achieved operational capability in November 2011 aboard the *Pacific Tracker*. Excellent data were collected on a test flight. During future BMD tests, XTR-1 will provide key data that are beyond the reach of ground-based instrumentation.
- As the Missile Defense Agency's (MDA) Counter-countermeasure Chief Scientist, Lincoln Laboratory leads MDA's technical efforts for defining discrimination solutions. Current efforts focus on developing a robust approach to missile defense lethal target identification and enforcement requirements for regional and theater threats.
- The Reagan Test Site (RTS) Distributed Operation (RDO) Program achieved initial operational capability for distributed

operations on 13 December 2011. The RDO system is revolutionizing how RTS conducts missions and supports range users. The first successful data collection was carried out on 23 February 2012.

- The Laboratory completed an Office of Naval Research Future Naval Capability program to provide integrated hard-kill and soft-kill engagement scheduling for future shipboard combat systems. A follow-on program will extend the previous work to develop and demonstrate multiship, force-level, hard-kill and soft-kill coordination.
- Lincoln Laboratory plays a critical role in the assessment and development of the current Command, Control, Battle Management, and Communications (C2BMC) system, and in trade analysis and demonstrations for the future system. The Laboratory supports the tracking,

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*Leadership*



Dr. Hsiao-hua K. Burke



Dr. Andrew D. Gerber



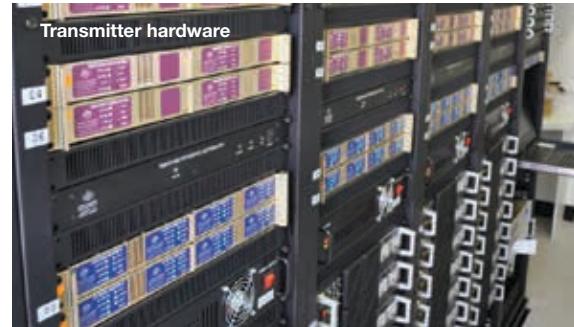
Mr. Gerald C. Augeri



Mr. Dennis J. Keane



Relocatable over-the-horizon radar



Portable receiver system

Lincoln Laboratory has had a significant role in the development and enhancement of over-the-horizon-radar (OTHR) capabilities for providing wide-area surveillance in support of the air, missile, and homeland defense communities. The Laboratory prototyped innovative signal processing techniques to reduce clutter and improve surveillance detection performance. Successful demonstrations of these techniques at the Relocatable OTHR facilities in the United States and at the Jindalee Operational Radar Network in Australia have led to potential architecture options for the design of a fully digital, next-generation system.

## Future Outlook

- correlation, integration, and discrimination analyses of the space-based sensor data into the C2BMC system.
- A test asset built to serve as a missile seeker surrogate was integrated onto a Falcon 20 aircraft for testing in 2010 and a Navy P-3 aircraft for testing in 2012 and beyond. The airborne test asset supports tests conducted by the Navy on a variety of new capabilities to counter antiship missile threats.
- The Laboratory conducted significant design and risk-reduction efforts for radar environmental characterization and clutter mitigation. These efforts will enhance the capability of MDA's X-band radars. Clutter mitigation algorithms have been extensively tested in modeling and simulation, and will be demonstrated during upcoming flight tests.
- The increasing vulnerability of deployed U.S. forces, and friends and allies, to large attacks by medium- and intermediate-range ballistic missiles mandates greater emphasis on improving regional BMD battlespace and raid-handling capabilities. Key responsibilities include development and test and evaluation of MDA's Phased Adaptive Approach.
- The Department of Defense is focusing on the emergence of anti-access and area-denial (A2AD) threats and how these threats drive the need for improved air and missile defense capabilities. The Laboratory is assisting the Office of the Secretary of Defense, MDA, and the Services in assessing the impact of these threats and in developing near-term modifications to existing systems, as well as longer-term advanced capabilities, to respond to these emerging threats.
- The Navy is looking toward developing more advanced soft-kill capabilities to complement the hard-kill capabilities on which it has traditionally relied for ship self-defense and is working on providing better electronic protection for its radar and missile systems. The Laboratory is helping shape a technology portfolio to ensure that the Navy's electronic warfare capabilities are adequately addressed across platforms and weapons systems.
- To enhance the credibility of deployed missile defenses, ground and flight tests must be planned and instrumented to verify the models and simulations used to assess capability. Lincoln Laboratory will continue to have a large role in test planning, test range and instrumentation improvements, and capability assessment.

# Communication Systems

Lincoln Laboratory is working to enhance and protect the capabilities of the nation's global defense networks. Emphasis is placed on synthesizing system architectures, developing component technologies, building and demonstrating end-to-end system prototypes, and then transferring this technology to industry for deployment in operational systems. Current efforts span all network layers (from physical to application), with primary focuses on radio-frequency military satellite communications, net-centric operations, free-space laser communications, line-of-sight networking, and human language technology.



This commercial interferometric fiber-optic gyroscope is being characterized for use as an inertial sensor to be mounted on lasercom terminals to enable extremely stable pointing for acquisition and tracking.

## Principal 2012 Accomplishments

- The Advanced Extremely High Frequency (AEHF) calibration facility/interim command-and-control terminals developed by Lincoln Laboratory established the first on-orbit protected communications with the AEHF-1 satellite and successfully performed the high-fidelity radiometric measurements needed to calibrate the payload's antennas.
- A small-form-factor protected satellite communications (SATCOM) modem for ground-based SATCOM-on-the-move applications was demonstrated. The modem includes the first information assurance architecture that is compliant with the new Security Classification Guide for EHF SATCOM.
- Using only ground-segment enhancements, the Laboratory demonstrated adaptive coding techniques that have the potential to increase the capacities of existing communications satellites by up to an order of magnitude.
- An architectural framework for the Airborne Tactical High-Performance Network Architecture program was defined, and the initial waveform designs for the Link 16 compatibility profile were completed.
- Recent air-to-ground laser communications (lasercom) demonstrations provided the first reported experimental evidence of scintillation reciprocity between single-mode receivers with near-unity correlation between power measurements at the receivers over a variety of channel conditions.
- A suite of software tools was deployed to the U.S. Pacific Command (PACOM) to increase flexibility, speed, and accuracy for developing situational awareness and command and control. The capabilities are helping reduce operational gaps at PACOM and are being demonstrated in Terminal Fury and Valiant Shield exercises.
- Flight testing of low-profile airborne military SATCOM antennas for operation at 44, 30, and 20 GHz was completed.
- The Lincoln Ka-Band Test Terminal was used to perform operational testing of the Wideband Global SATCOM System's wideband bypass mode for high-rate communications.
- A flight campaign characterized the performance of transfer-aligned inertial navigation systems and inertial measurement units. The data were

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*Leadership*



Dr. J. Scott Stadler



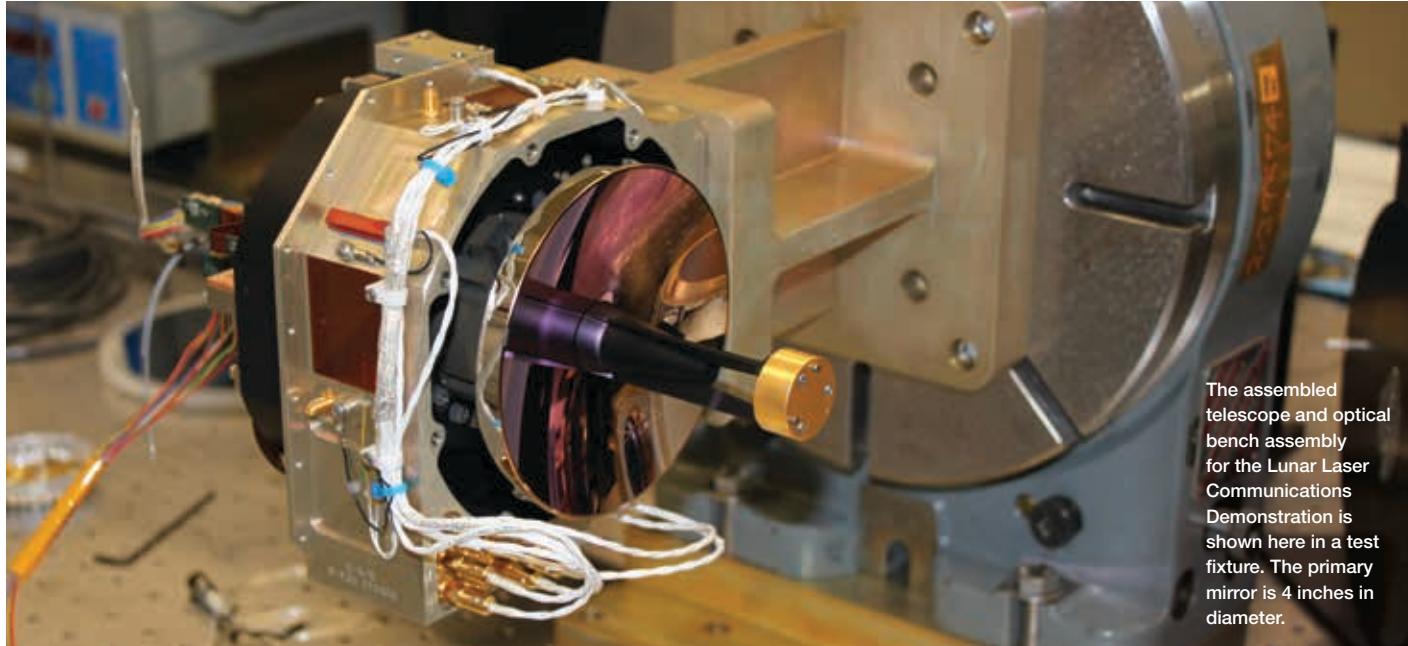
Dr. Roy S. Bondurant



Mr. Stephan B. Rejto



Dr. Marc A. Zissman



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## Future Outlook

evaluated with respect to open-loop pointing requirements for lasercom terminals over a range of platform characteristics and concepts of operation.

- The Lunar Laser Communications Demonstration program is on track to deliver lasercom terminals for NASA's first demonstration of optical communications. The link between NASA's satellite in a lunar orbit and Earth will be the longest-distance, free-space, optical communications ever achieved.
- An enhanced, forensic-style, speaker-comparison tool uses state-of-the-art session and channel compensation as well as speech enhancement. The tool provides robustness to cross-channel operating conditions, a fivefold performance improvement, and a fourfold speed enhancement over previous tools.

■ Net-centric cyber situational awareness efforts will expand by increasing the number of integrated data sources and broadening the depth and breadth of decision support tools.

■ Human language technology work will include the synthesis of algorithms to develop advanced content-based analytics, including target discovery, knowledge-base population, intent recognition, and crossmedia knowledge discovery.

■ Foundational technology efforts will continue in several areas:

- Development of processes to fabricate quantum-dot devices at telecommunications wavelengths that will have quantum and classical communications applications
- Progress toward the demonstration of loophole-free violation of Bell's inequality with applications to information security
- Improvements in the scalability and robustness of superconducting, nanowire, single-photon detectors

■ Lincoln Laboratory will explore transceiver designs that exploit scintillation reciprocity to achieve low-latency systems operating at near theoretical channel capacity by adapting transmission on the basis of near-real-time knowledge of the channel state.

■ Software capability deliveries for developing situational awareness and performing command and control (C2) will expand from PACOM to U.S. Southern Command.

# Cyber Security

Lincoln Laboratory conducts research, development, evaluation, and deployment of prototype components and systems designed to improve the security of computer networks, hosts, and applications. A particular focus is the intersection between the Laboratory's traditional mission areas and the cyber domain. Efforts include cyber analysis; creation and demonstration of robust architectures that can operate through cyber attacks; development of prototypes that demonstrate the practicality and value of new techniques for cryptography, cyber sensing, automated threat analysis, anti-tamper systems, and malicious code detection; demonstrations of the impact of cyber on traditional kinetic systems; quantitative, repeatable evaluation of these prototypes; and, where appropriate, deployment of prototype technology to national-level exercises and operations. The Laboratory develops and deploys control and traffic-generation software for many of the Department of Defense's (DoD) largest cyber ranges.



Lincoln Laboratory, under sponsorship from the U.S. Air Force Cryptographic Modernization Program Office, is developing a one-size-fits-many soft-core standalone crypto processor, known as SHAMROCK. The SHAMROCK processor provides a set of standard, interoperable cryptographic algorithms and implements important key management functions, including over-the-air keying for distributing cryptographic keys securely over unsecured communication channels. SHAMROCK offers major security, power, and performance benefits; it is targeted at applications for resource-constrained devices, such as small unmanned vehicles and handheld devices. The Laboratory performed a functional demonstration of the chip in April 2012 and is scheduled to complete a reference design and deliver it to the sponsor in fall 2012.

## Principal 2012 Accomplishments

- Researchers worked with government sponsors to publish comprehensive enterprise cyber security metrics that are grounded in realistic attacker models and that enable repeatable assessment of cyber risk for comparison from one organization to another.
- Lincoln Laboratory researchers supported efforts of the Assistant Secretary of Defense for Research and Engineering to develop road maps for future DoD cyber research and cyber measurement campaigns. These plans are expected to heavily influence future DoD-wide cyber investments.
- Laboratory researchers designed, developed, and deployed cyber situational awareness systems at several DoD national and mission operations centers, including the U.S. Cyber Command and U.S. Pacific Command. These systems share a common net-centric architecture in which data feeds and analytic services are discoverable, extensible, and composable. Feedback from operational use is driving ongoing development of new analytical and visualization tools.
- The Laboratory established the Lincoln Research Network Operations Center (LRNOC) to develop prototype cyber analysis tools by processing the Laboratory's own operational network traffic, security system alerts, information technology system logs, and configuration data. The LRNOC serves as a test bed for exploring and evaluating new techniques prior to prototype deployment on DoD networks.
- The development of effective, dynamic, cryptographic key management techniques for small tactical systems continued. Laboratory researchers published a key management architecture for small unmanned aircraft systems, and then worked with government and commercial organizations to establish elements of this architecture as a standard for widespread use.
- The Laboratory assessed the performance of numerous cyber components and systems for a wide variety of DoD sponsors, including the Defense Advanced Research Projects Agency (DARPA) and the Air Force. Sponsors were able to use the results of these assessments to understand the maturity and effectiveness of these components and systems for DoD missions.



Dr. Marc A. Zissman



Mr. Stephan B. Rejto



Dr. Robert K. Cunningham



Mr. Lee M. Rossey



Mr. Joshua W. Haines



LEFT: Lincoln Laboratory researchers Matt Johnson and Ben Bulloch collect RF signals from a tactical system during field tests that were used to assess potential cyber vulnerabilities of the system.

ABOVE: In the Lincoln Research Network Operations Center, Kim Hebert, Kendra Kratkiewicz, and Jeremy Mineweaser analyze results from a next-generation, prototype, spear-phishing email detection system.

## Future Outlook

- The Laboratory continued the development of the Lincoln Adaptable Real-time Information Assurance Testbed (LARIAT) software suite. LARIAT is used to configure, command, and control large-scale experiments on cyber ranges, and has been deployed to many dozens of DoD cyber ranges nationwide. The Laboratory worked on enhancing and deploying LARIAT components, including high-fidelity hardware-based cyber sensors, low-artifact traffic actuators, and autonomous Web 2.0 traffic generation.
- Lincoln Laboratory will continue to architect and analyze DoD mission-critical systems to ensure that these systems will be effective in a contested cyber domain. Over time, this cyber architecture and analysis work should extend to support all or most of the Laboratory's mission areas.
- Over the next year, the Laboratory will validate the metrics developed to assess the security posture of government enterprise-class networks. The long-term goal is to have these quantitative and threat-relevant metrics replace the checklist-based and threat-independent metrics used in current assessments.
- Technologies being developed under DARPA's Clean-slate Design of Resilient Adaptive Secure Hosts (CRASH) program will be integrated into one or more prototypes that can be evaluated as whole systems. The evaluations will help DARPA assess this program that is investigating techniques for securing computer components and systems.
- The Laboratory will continue work on the following initiatives:
  - Developing cyber situational awareness technology for use at the enterprise, mission, and national levels
  - Providing high-quality assessments of cyber systems and capabilities
  - Developing and deploying cutting-edge technologies to create and support high-fidelity cyber experiments
  - Advancing malicious-software analysis, triaging, and categorization capabilities

# Intelligence, Surveillance, and Reconnaissance Systems and Technology

To expand intelligence, surveillance, and reconnaissance (ISR) capabilities, Lincoln Laboratory conducts research and development in advanced sensing, signal and image processing, automatic target classification, decision support systems, and high-performance computing. By leveraging these disciplines, the Laboratory produces novel ISR system concepts for both surface and undersea surveillance applications. Sensor technology for ISR includes passive and active electro-optical systems, surface surveillance radar, radio-frequency (RF) geolocation, and undersea acoustic surveillance. Increasingly, the work extends from sensors and sensor platforms to include the processing, exploitation, and dissemination architectures that connect sensors to operational users. Prototype ISR systems developed from successful concepts are then transitioned to industry and the user community.



Technical staff are developing approaches for automated data exploitation in the new ISR processing, exploitation, and dissemination (PED) laboratory.

## Principal 2012 Accomplishments

- Work continued on next-generation, wide-area, motion imaging systems. In 2012, Lincoln Laboratory deployed three systems for operational testing: Multi-aperture Sparse Imager Video System (MASIVS)—an 880 Mpixel, color, airborne sensor; Wide-area Infrared System for Persistent 360° Surveillance (WISP-360)—a 100 Mpixel, infrared, ground-based sensor for base protection; and Imaging System for Immersive Surveillance (ISIS)—a 240 Mpixel, color, ground-based optical sensor for critical infrastructure protection. Common among these persistent systems are the processing and exploitation tools that provide stitching, compression, geostabilization, target tracking, multi-intelligence fusion, and visualization.
- The Laboratory developed a next-generation, three-dimensional, imaging
- Ladar for the U.S. Southern Command. This system is optimized for finding man-made structures under dense foliage canopy with area collection rates significantly higher than the rates of any existing ladar system. After system demonstrations this year, the sensor will undergo operational testing.
- Improved maritime surveillance radar signal processing techniques were developed and demonstrated for several target classes. These techniques were assessed with substantial experimental data and will likely transition to current and future maritime radar systems.
- Passive sonar detection and ranging algorithms were developed to improve submarine undersea situational awareness. These algorithms help better localize potential collision threats, and are scheduled for operational Fleet deployment following system and at-sea testing.
- The Laboratory provided the U.S. Air Force with technical assessments of future ground moving target indication (GMTI) radar system options for performing conventional and irregular warfare missions. The Laboratory is supporting the development of a new radar that utilizes unique radar signal processing and radar open system architecture technology. The radar will be fielded on an MQ-9 unmanned air vehicle.
- For automated exploitation of GMTI radar data, the Laboratory's Pyxis software was operationally deployed to several government sites. This system has proven useful in automating the pattern of life analysis, reducing the timeline for useful analysis, and improving the detection of

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*Leadership*



Dr. Robert T-I. Shin



Mr. Robert A. Bond



Dr. Curtis W. Davis III



Dr. James Ward



Dr. William D. Ross



Staff members are deploying ship-based signal sources as part of the Laboratory's work evaluating surveillance radar performance in maritime environments.

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## Future Outlook

subtle activity patterns. Extensions to other sensor types are under way.

- The Laboratory developed algorithms and software tools for analyzing extremely large unstructured intelligence datasets. These tools have proven effective at automated data mining and analysis, and were deployed on remote, data-intensive, computing centers.
- Research into statistical inference on very large graphs has begun to show promising results on real-world problems in ISR and cyber security. Techniques to detect anomalies in the topology of a community within a large network were developed and effectively demonstrated. New software tools are enabling rapid accessing of large databases and MATLAB-based algorithm prototyping.
- Significant efforts supporting the Air Force with architecture engineering, systems analysis, technology development, and advanced capability prototyping are expected, but with increasing emphasis on security challenges in the Asia-Pacific region.
- Enhanced activities in electronic warfare and in Navy maritime and undersea surveillance are expected as part of the national shift to security challenges in the Asia-Pacific region.
- Emphasis on ISR data exploitation will continue as new wide-area sensing capabilities are fielded. Research will focus on techniques for fusion and statistical inferencing with multisource sensor data and non-sensor data sources.
- The Laboratory will help the government develop, prototype, and employ open system architecture paradigms in sensors, unmanned system ground control stations, and future common ground systems for data exploitation.
- Enhanced activity in airborne RF geolocation systems will evolve in response to the evolution of commercial computing and networked communications technology.
- Laser-based sensing will expand into new applications as the technology for optical waveforms and coherent laser-based sensing improves.

# Tactical Systems

Lincoln Laboratory assists the Department of Defense in improving the acquisition and employment of various tactical air and counterterrorist systems by helping the U.S. military understand the operational utility and limitations of advanced technologies. Activities focus on a combination of systems analysis to assess technology impact in operationally relevant scenarios, rapid development and instrumentation of prototype U.S. and threat systems, and detailed, realistic, instrumented testing. A tight coupling between the Laboratory's efforts and the DoD sponsors and warfighters involved in these efforts ensures that these analyses and prototype systems are relevant and beneficial to the warfighter.



ABOVE AND RIGHT: The Laboratory is developing a novel ground-penetrating radar capability to be used by combat engineers. An initial prototype has been integrated onto an Army Husky vehicle.

## Principal 2012 Accomplishments

- Lincoln Laboratory continued its comprehensive assessment of U.S. Air Force airborne electronic attack options against foreign air defenses. Analysis, modeling, prototyping, and testing of conventional and advanced electronic attack systems were leveraged to inform acquisition decisions regarding next-generation electronic attack systems.
- The Laboratory's Airborne Countermeasures Test System aircraft was enhanced; the aircraft supported captive-carry testing of infrared sensors and electronic attack systems, as well as advanced fighter radar development.
- Assessment of digital RF memory-based electronic attack impacts on air-to-air weapon systems continued. Systems analysis, advanced surrogate development, and hardware-in-the-loop and flight testing enabled U.S. electronic protection system improvements, and informed DoD's leadership decision-making on future investments.
- Capabilities and limitations of infrared sensors and seekers to support passive, air-to-air engagements were characterized through testing and system-level assessments.
- The Laboratory's examination of the impacts of advanced military system export will support Congress and the Under Secretary of Defense for Acquisition, Technology, and Logistics in decision-making for a number of major export programs.
- The Laboratory initiated the prototyping of four Air Force quick-reaction capabilities fielding new intelligence, surveillance, and reconnaissance (ISR) capabilities developed at Lincoln Laboratory.
- Several novel airborne signals intelligence capabilities were developed and demonstrated. Prototypes were transitioned to operational use, and technology is being transitioned to industry.
- The Laboratory developed and supported quick-reaction counterterrorism capabilities, including novel ground-penetrating radar, a unique robot-mounted sensor system, and two innovative airborne sensors developed as elements of a fielded, multi-intelligence, ISR capability.
- A Family of Systems architecture engineering team was established and assisted the Air Force with system-of-systems integration challenges.

*Leadership*



Dr. Robert T-I. Shin



Dr. Justin J. Brooke



Dr. Melissa G. Choi



Dr. Kevin P. Cohen



Dr. Marc N. Viera

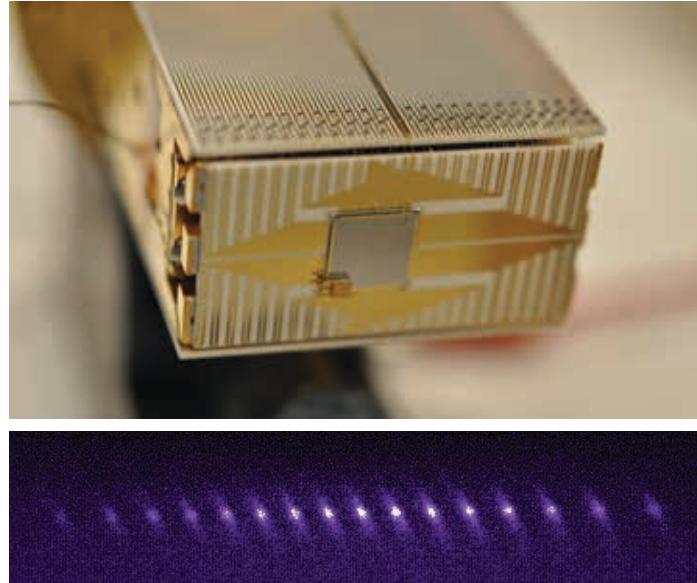


## Future Outlook

- An Advanced Concepts and Technologies Team was formed to provide the Air Force with innovative concepts, system assessments, and rapid prototyping for enhancing air-vehicle effectiveness.
- The Information Dominance Assessment Team supported the Air Force with assessments and risk-reduction efforts in areas including ground moving target indication radar, advanced infrared and ladar sensors, and processing, exploitation and dissemination.
- The Laboratory evaluated threats to U.S. space systems and assessed measures to preserve capabilities in the face of these threats.
- Significant efforts supporting the Air Force with architecture engineering, systems analysis, technology development, and advanced capability prototyping will continue, but with increasing emphasis on security challenges in the Asia-Pacific region.
- The Laboratory's continuing emphasis on threat prototyping will be leveraged to better inform DoD acquisition decisions.
- In consideration of changing acquisition paradigms, the Laboratory will expand its rapid development capabilities.
- Efforts in the counterterrorism area will broaden from support of deployed forces to a more global focus.

# Advanced Technology

Research and development in Advanced Technology support the entire Laboratory by identifying new phenomenologies that can be exploited in novel system applications and by developing revolutionary advances in subsystem and component technologies that enable new system capabilities. This work is highly multidisciplinary, leveraging solid-state electronic and electro-optical technologies, innovative chemistry, and advanced radio-frequency (RF) technology. Recent developments include world-class imagers and detectors, novel three-dimensional electronic-photonic integration techniques, unique digital and quantum information systems technology, novel engineered materials, chemical-agent sensors, state-of-the-art lasers and photonic devices, and advanced antenna arrays and RF transceivers.



A superconducting ion-trap chip, top, on a cryogenic stage, and a linear array, below, containing 16 individual strontium ions trapped 50  $\mu$ m from the surface of the chip.

## Principal 2012 Accomplishments

- Lincoln Laboratory researchers were the first to report loading of an ion trap using atoms held in a remotely located magneto-optical trap (MOT). (Others have trapped ions from a MOT, but only a collocated MOT, which has disadvantages associated with isotopic purity and surface contamination.) The remote approach results in a tenfold increase in loading times and will be important for large-scale experiments leading to a future quantum computer.
- Record performance has been achieved with 1  $\mu$ m wavelength slab-coupled optical waveguide lasers (SCOWL) and amplifiers (SCOWA). For SCOWAs operating at  $>1$  W continuous wave (CW) single-mode output powers, electrical-to-optical efficiencies of up to 40% have been achieved. A SCOWA array comprising 47 individually seeded and addressable elements was packaged, and raw power of up to 57 W CW ( $\sim 1.2$  W per SCOWA) was obtained. By using active phase control of each semiconductor amplifier, CW output of more than 50 W was obtained in a single output beam from such an array when combined. Single-mode SCOWL devices with output powers up to  $\sim 3$  W CW have also been achieved.
- Broad-spectrum viral therapeutics continued to be an important research target in biotechnology, as they can provide protection to warfighters and civilians against current or future threats of contagious diseases. A class of chimeric biomolecules was invented at Lincoln Laboratory, prepared in the laboratory, and recently tested successfully in mice that were infected with dengue hemorrhagic fever. This approach will be tested against other viruses, including some in Biosafety Level-3 and -4 laboratories.
- A low-phase-noise, 3 GHz, optoelectronic oscillator operating without electrical amplification was enabled by the incorporation of a high-power, low-relative-intensity-noise, slab-coupled optical waveguide, external-cavity laser and a high-current SCOW photodiode.
- The Laboratory offered access to ultra-low-power (ULP), fully depleted silicon-on-insulator (FDSOI), complementary metal-oxide-semiconductor (CMOS) technology across the Department of Defense (DoD) community through a multiproject run sponsored by the Defense Advanced Research Projects Agency (DARPA). Working with

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*Leadership*



Dr. Robert G. Atkins



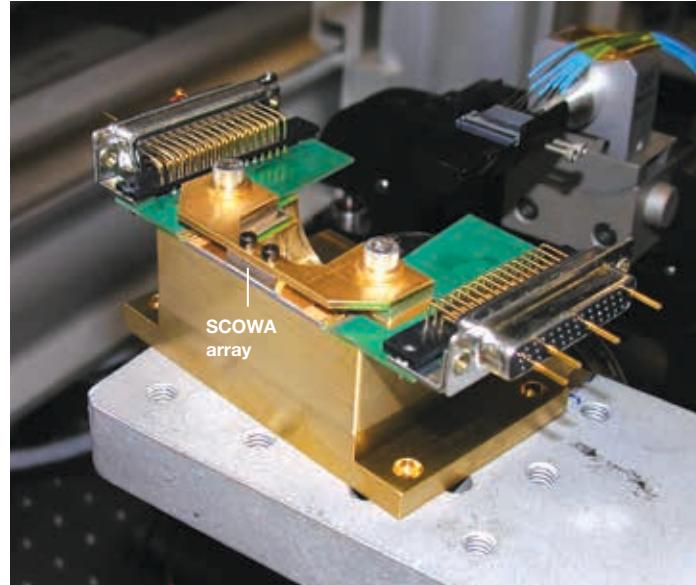
Dr. Craig L. Keast



Dr. Simon Verghese



William Spencer is working at the SAMCO oxide deposition system in the compound semiconductor fabrication room. This system is used to deposit oxide films as part of the many device fabrication steps required for the demonstration of record performance slab-coupled optical waveguide lasers (SCOWLs) and amplifiers (SCOWAs).



The 57 W, 1  $\mu$ m wavelength, laser module comprises 47 individually addressable SCOWAs in a 5 mm long, single-pass cavity.

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## Future Outlook

modern tools in the recently recapitalized Microelectronics Laboratory, Lincoln Laboratory delivered chips with 26 unique external ULP circuit designs submitted by university partners. Circuit designs and electrical results from contributors were presented at the IEEE Subthreshold Microelectronics Conference. This very successful conference, which featured more than 50 contributed talks and drew nearly 100 attendees, established Lincoln Laboratory as a leader in the emerging field of subthreshold microelectronics.

- Breakthroughs in phenomenological understanding and revolutionary advances in subsystem and component technologies will continue to enable the novel sensing, computation, and communication systems needed by evolving national security applications.
- The Laboratory will develop unique, world-class imagers for national security and science applications.
- Significant effort will be invested in supporting defense needs for high-energy lasers.
- The Laboratory will advance chemical-sensing technologies for detection of explosives and other chemical agents.
- The development of RF technology is aimed at supporting next-generation military radar and electronic warfare needs.
- Responding to the slowing size and speed scaling of silicon devices, the Laboratory will explore a variety of “beyond silicon” pathways, including three-dimensional integration, mixed materials, electronic-photonic circuit integration, graphene electronics, and quantum information science.

# Homeland Protection

The Homeland Protection mission supports the nation's security by innovating technology and architectures to help prevent terrorist attacks within the United States, to reduce the vulnerability of the nation to terrorism, to minimize the damage from terrorist attacks, and to facilitate recovery from either man-made or natural disasters. The broad sponsorship for this mission area spans the Department of Defense, the Department of Homeland Security (DHS), and other federal, state, and local entities. Recent efforts include architecture studies for the defense of civilians and facilities, new microfluidic technologies for DNA assembly and transformation and for gene synthesis, development of the Enhanced Regional Situation Awareness system for the National Capital Region, the assessment of technologies for border and maritime security, and the development of architectures and systems for disaster response.

RIGHT: U.S. Army Fellow Lieutenant Colonel Scott Jackson loads DNA samples for processing in the Accelerated Nuclear DNA Equipment (ANDE) prototype instrument. The microfluidic-based system is designed to be operated by technicians in expeditionary laboratory facilities to enable rapid, accurate human identification.



## Principal 2012 Accomplishments

- The Imaging System for Immersive Surveillance (ISIS) consists of a custom 240 Mpixel sensor, a multi-terabyte data archive, a multiple-user video interface, and automated video exploitation algorithms for ground-based surveillance in support of critical infrastructure protection. Sponsored by the DHS Science and Technology Directorate (DHS S&T), ISIS is being operationally tested in multiple venues such as airport terminals.
- The Next-Generation Incident Command System (NICS), developed in partnership with the California Department of Forestry and Fire Protection (CAL FIRE) is being deployed statewide by CAL FIRE and exercised by first responders in a DHS S&T sponsored Northeast Pilot including the Massachusetts Emergency Management Agency (MEMA) and the Fire Department of New York (FDNY).
- The Laboratory continues to lead technology development and architectures for countering chemical threats. Accomplishments include threat phenomenology measurements, gap and technology analysis, and design and testing of new capabilities for warfighters and the homeland.
- The Laboratory is working with the U.S. Army Research Institute of Environmental Medicine to develop advanced physiological monitoring sensors, signal processing algorithms, and open architectures that will reduce heat casualties among service members. Field tests were conducted with the 22nd Chemical Battalion to assess thermal strain while personnel were wearing protective gear.
- Lincoln Laboratory is advancing video-analytics technology for performing attribute-based search and for tracking suspects across arrays of conventional security cameras. The domain includes wide-area airborne and ground-based camera surveillance of locations and vehicles in and around buildings, ports, and waterways.
- Support continues for architectures and technology assessments to fill capability gaps in homeland air surveillance. Key focuses include architectural support to an Analysis of Alternatives led by the Air Force, upgrades to the National Capital Region's air defense, and mitigations for wind-turbine interference on ground-based radar.
- Under the sponsorship of DHS S&T, the Laboratory developed a mobile, trace-chemical collection and detection system for maritime cargo security. The system is being used to assess detection technologies

*Leadership*



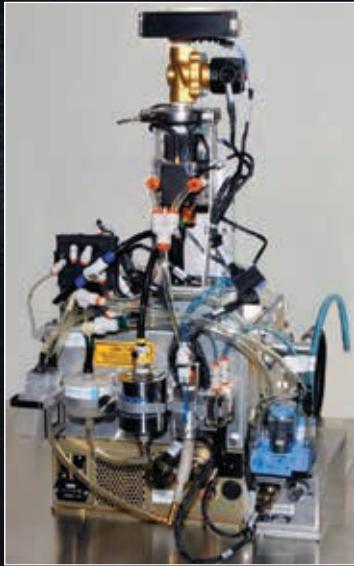
Dr. Israel Soibelman



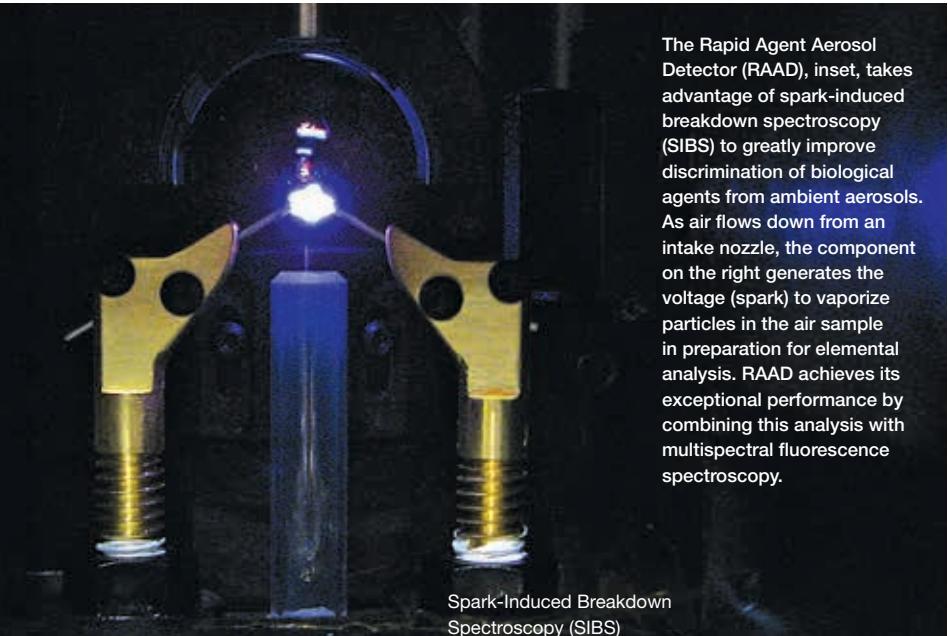
Mr. James M. Flavin



Dr. Timothy J. Dasey



Rapid Agent Aerosol Detector (RAAD)



Spark-Induced Breakdown Spectroscopy (SIBS)

The Rapid Agent Aerosol Detector (RAAD), inset, takes advantage of spark-induced breakdown spectroscopy (SIBS) to greatly improve discrimination of biological agents from ambient aerosols. As air flows down from an intake nozzle, the component on the right generates the voltage (spark) to vaporize particles in the air sample in preparation for elemental analysis. RAAD achieves its exceptional performance by combining this analysis with multispectral fluorescence spectroscopy.

## Future Outlook

- and collect phenomenology data in operational port environments.
- The Laboratory is supporting U.S. Coast Guard acquisition strategies through architecture and technology assessments for search and rescue, port security, cargo vessel targeting, and environmental protection missions.
- The field-deployable Accelerated Nuclear DNA Equipment program delivered five prototype units for transition to the Departments of Defense, Justice, and Homeland Security. Through industry participation (Network Biosystems), a six-channel prototype now automatically produces DNA profiles within 90 minutes. Lincoln Laboratory also developed collection techniques and a secure privacy-preserving framework for processing, storage, and analysis.
- National interest in improved critical infrastructure protection, emergency preparedness, and disaster response will prompt advancements in information sharing, decision support, and situation awareness technologies to integrate first responder communities. Solutions will leverage Lincoln Laboratory's strengths in net-centric architectures, deployable sensors, and informatics such as data and video analytics.
- The Laboratory will continue to lead development, analysis, and testing of advanced chemical and biological defense, biometric, and forensic technologies for theater and homeland protection. Key areas include sensors, DNA sequencing and identification techniques, and data fusion algorithms.
- Bioengineering research in synthetic biology will lead to the development of microfluidic devices for rapid genome scale prototyping, and research in biomedical sensing and analysis will implement miniaturized sensors and algorithms for physiological monitoring.
- Securing and defending U.S. borders will continue to motivate studies to define an integrated air, land, and maritime architecture and will spur advanced sensor, data fusion, and decision support technology development.
- The Laboratory will support the U.S. Coast Guard in the development of architectures and technologies for securing the port environment.

## Air Traffic Control

Since 1971, Lincoln Laboratory has supported the Federal Aviation Administration (FAA) in the development of new technology for air traffic control. This work initially focused on aircraft surveillance and weather sensing, collision avoidance, and air-ground data link communication. The program has evolved to include safety applications, decision support services, and air traffic management automation tools. The current program is supporting the FAA's Next Generation Air Transportation System (NextGen). Key activities include the operation of a national-scale integrated weather-sensing and decision support prototype, testing and technology transfer of a runway incursion-prevention system, development of a future air traffic control tower automation platform, and the development of a net-centric, system-wide information management system.



The next-generation, airborne collision avoidance system, ACAS X, initial hardware prototype is currently undergoing bench testing.

### Principal 2012 Accomplishments

- The Tower Flight Data Manager (TFDM) is a first-of-its-kind, integrated, air traffic control automation system that provides situation awareness and decision support functions for managing and improving the safety and efficiency of airport operations. The Laboratory focused this year on an in-depth analysis of operational efficiency improvements that will be realized when TFDM is employed.
- Lincoln Laboratory plays a key role for the FAA in developing the next-generation (NextGen) airborne collision avoidance system, ACAS X. Research efforts showed that the ACAS X alerting logic will reduce the frequency of nuisance alerts by 50% while improving safety over the current Traffic Alert and Collision Avoidance System (TCAS). As a result, the FAA has formalized the ACAS X program. The Laboratory's efforts in 2012 are focused on preparing for flight trial with a hardware prototype in 2013.
- The NextGen Weather Processor (NWP) consolidates multiple, legacy FAA weather processing platforms and introduces new functionality such as the 0–8 hr thunderstorm-forecasting technology developed by Lincoln Laboratory. The Laboratory is leading efforts to refine requirements for NWP, develop a reference technical architecture, and provide technology exhibits for use by the FAA in requests for proposals from industry.
- Ten active array panels will be fabricated, integrated, and tested to demonstrate affordable phased-array radar technology for meeting next-generation FAA weather and noncooperative target surveillance requirements. In addition, the Laboratory is performing an analysis to clarify applications and requirements for primary radars in the future National Airspace System (NAS), for example, in sense-and-avoid (SAA) systems for unmanned aerial systems (UAS).
- Integration of UASs into the NAS continues to be a high priority. The Laboratory is working within the UAS community through the FAA and RTCA, Inc. to develop standards and requirements to fulfill UAS SAA requirements. The Laboratory extended the ACAS X collision avoidance algorithms for manned aircraft to support both ground-based and airborne SAA for UASs. In support of the Army, the Laboratory deployed a reference ground-based

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*Leadership*



Dr. Mark E. Weber



Mr. James M. Flavin



Dr. James K. Kuchar



Dr. Gregg A. Shoultz



Dr. Marilyn M. Wolfson



The Corridor Integrated Weather System (CIWS), recently integrated into the Traffic Flow Management System as shown here at the New York Air Route Traffic Control Center, is used in more than 80 FAA facilities across the United States to strategically manage air traffic during periods of severe weather.

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## Future Outlook

SAA architecture to Dugway, Utah, with UAS flight trials beginning in June. The Laboratory's conflict-avoidance logic will also be tested in an Air Force ground-based SAA architecture in July at Gray Butte, California.

■ For the Department of Homeland Security, the Air Traffic Control mission is partnering with the ISR and Tactical Systems Division to develop and test a lightweight, low-power, airborne radar to support SAA. A hardware prototype of the radar will be tested on the Laboratory's flight-test aircraft in fall 2012.

- Lincoln Laboratory will apply its expertise in surveillance processing, data management, algorithms, and human systems integration to increase its role in developing future NextGen concepts, including Trajectory Based Operations, Automatic Dependent Surveillance–Broadcast applications, advanced data communications, and surface operations management.
- The Laboratory will continue requirements definition, prototyping, and technology transfer support for next-generation weather capabilities. These include decision support tools for managing arrivals into congested airports during severe weather and algorithms for estimating the capacity reductions caused by thunderstorms in en route sectors.
- Support for current and future FAA safety systems will continue. As the Runway Status Lights (RWSL) system is deployed to 22 airports around the country, the Laboratory will assess advanced capabilities, including lights supporting high-speed operations at intersecting runways and Final Approach Runway Occupancy Signals (FAROS). The Laboratory will continue to monitor current TCAS performance and will conduct flight tests of ACAS X.
- The Laboratory will support human-in-the-loop trials at the FAA Technical Center to assess concepts for integrating UAS sense-and-avoid systems with commercial aircraft collision avoidance systems. In addition, a comprehensive safety assessment for UAS operations in civil airspace will include determining target level of safety, modeling collision avoidance performance, and characterizing relevant parameters of the U.S. airspace.

# Engineering

Fundamental to the success of Lincoln Laboratory is the ability to build hardware systems incorporating advanced technology. These systems are used as platforms for testing new concepts, as prototypes for demonstrating new capabilities, and as operational systems for addressing warfighter needs. To construct the variety of systems used in programs across all mission areas, the Laboratory relies on its extensive capabilities in mechanical design and analysis, optical system design and analysis, aerodynamic analysis, mechanical fabrication, electronics design and assembly, control system development, system integration, and environmental testing. These capabilities are centered in the Laboratory's Engineering Division, which is an important contributor to many of the Laboratory's most successful efforts.



## Principal 2012 Accomplishments

- Lincoln Laboratory hosted its first annual Mechanical Engineering Technology Symposium on 26 September 2011. The symposium highlighted initiatives on a wide range of fundamental mechanical engineering issues that included the impact of electrical discharge machining on titanium fatigue life, the prediction of solder-joint fatigue life, structural modeling of bolted joints, and integrated aero-optical analysis.
- Assembly of the qualification and flight units' space terminal optical module and the flight modem for the Lunar Laser Communications Demonstration was completed. The qualification unit was tested with fully functional engineering development units of the modem and controller. The flight unit underwent environmental testing in summer 2012.
- The Laboratory made investments in new equipment in order to maintain its cutting-edge fabrication capability. The installation of two five-axis milling machines is allowing more accurate and faster fabrication of high-precision mechanical components.
- In a rapid prototyping effort, a sprayer system for use by U.S. Army and National Guard Civil Support Teams responding to chemical-agent attacks was developed with commercial parts and in close coordination with future users. The system met aggressive weight and cost goals and is currently under consideration for transition to an industrial partner.
- The Laboratory completed the mechanical design and field testing of a ground-based, wide-area, surveillance system, and will continue with the fabrication and assembly of a small number of prototype systems for field evaluation.
- Completion of the shipboard mechanical installation of all components of the X-band Transportable Radar (XTR-1) system included the assessment and correction of the antenna balance, fabrication and installation of a new antenna bull gear, and an upgrade of system cooling loops. Following this work, the system participated in its first mission.

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*Leadership*



Dr. Eliahu H. Newood



Dr. William R. Davis



Dr. Michael T. Languirand



Lincoln Laboratory completed the mechanical installation of all components of the X-band Transportable Radar (XTR-1), the large-scale, ship-based RF system. Shown clockwise from far left are the reflector installation, feed installation, the radome being lowered over the dish, and the completed radar on the *Pacific Tracker*.

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## Future Outlook

- The Laboratory developed a mobile system that tests air in cargo containers for chemical agents. The system employs a robotic arm for sealing an airflow plenum against the container vent. Two truck-mounted systems were built for testing at various cargo facilities, and the test data will be used to evaluate the system's future usage.
- Lincoln Laboratory is developing plans for a new building to house the Engineering Division. An internal team is working to identify engineering practices and technical capabilities that need to be reflected in the design of a new, state-of-the-art facility for supporting prototyping efforts.
- Investments to ensure cutting-edge capabilities in the design, fabrication, and assembly areas will continue. In the near future, the Laboratory will transition to new mechanical computer-aided design and product lifecycle management tools. These tools will enable better integration of mechanical design with other Laboratory activities and more efficient use of designer resources.





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## Educational Collaborations with MIT

### Mentors for MIT's Product Engineering Processes Course

Twelve technical staff members volunteered as mentors to student teams from the Product Engineering Processes course offered in the fall semester by MIT's Department of Mechanical Engineering. The teams of 14 to 16 students take a concept for a new product and turn it into a functional prototype. Lincoln Laboratory mentors help guide the design and fabrication of innovative, diverse products ranging this year from a clothes-compacting suitcase to a bicycle-helmet vending machine to a water-faucet attachment that monitors a sink's fill rate. "We try not to intrude on their projects, but help them understand the implications of their decisions," explains mentor Gregory Cappiello.

The fall 2011 mentors were Joseph Bari, Daniel Kettler, Michael Stern, and Scott VanBroekhoven from the Rapid Prototyping Group; Gregory Cappiello of the Optical Systems Engineering Group; Allyn Dullighan, Matthew Johnson, Benjamin Lapointe, and John Norstrom of the Tactical Defense Systems Group; Dr. Eric Statz of the Active Optical Systems Group; David Tardiff of the Mechanical Engineering Group; and Dr. Jesse Linnell of the Advanced System Concepts Group. In addition, Loren Wood of the Surveillance Systems Group served as an instructor for a team.

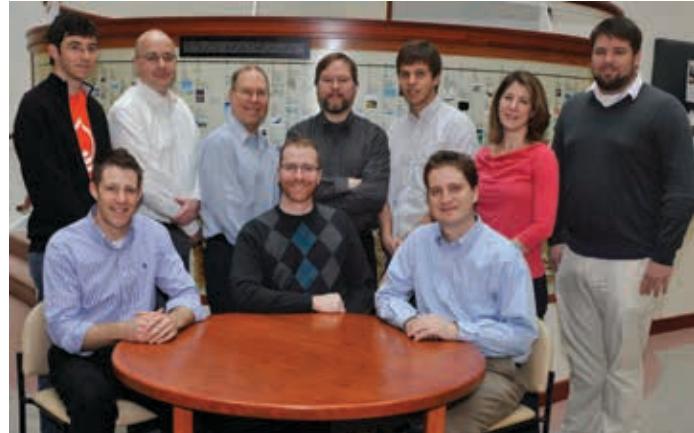
**MIT VI-A Master of Engineering Thesis Program**  
 Four MIT students in the VI-A Master of Engineering Thesis Program were hired in summer 2012 to work with Laboratory mentors while gaining experience in testing, design, development, research, and programming. Students in the VI-A program spend two summers as paid interns, participating in projects related to their fields. Then, the students are paid as research assistants while developing their master of engineering theses under the supervision of both Laboratory engineers and MIT faculty.

### Research Assistantships

Lincoln Laboratory employs research assistants from MIT. Working with engineers and scientists, the assistants contribute to programs while investigating the questions that evolve into their doctoral theses. The facilities, research thrusts, and reputations of staff members are prime inducements behind the graduate students' decision to spend three to five years as a research assistant in a Laboratory group. Currently, 18 research assistants are working in various divisions.

### Undergraduate Research Opportunities Program

In 2012, 12 undergraduates were hired in the summer as part of the MIT Undergraduate Research Opportunities Program (UROP), which allows students to participate in every aspect of onsite



Lincoln Laboratory technical staff who mentored student teams from MIT's Department of Mechanical Engineering product development course are (seated, left to right) Matthew Johnson, Jesse Linnell, and Eric Statz; (standing, left to right) Benjamin Lapointe, Greg Cappiello, Loren Wood, David Tardiff, Michael Stern, Allyn Dullighan, and John Norstrom. Missing from the photograph are Joseph Bari, Daniel Kettler, and Scott VanBroekhoven.

research. Students develop research plans, write proposals, perform experiments, analyze data, and present research results.

### Undergraduate Practice Opportunities Program

Lincoln Laboratory participates in MIT's Undergraduate Practice Opportunities Program (UPOP). This full-year program for MIT sophomores is an introduction to workplace skills that complement students' academic training. An important facet of the program is a summer internship in industry, government, or a nonprofit institution. As a UPOP partner, the Laboratory offers internships during which the MIT students use the lessons learned from both academic courses and career coaching experiences. In summer 2012, four UPOP students worked at the Laboratory.

### MIT Professional Education—Short Programs

Lincoln Laboratory is collaborating on three courses offered through MIT's Professional Education Short Programs. Short Programs run during the summer and bring participants from industry, government, and business to the campus for intensive, week-long courses designed to expand participants' familiarity with emerging technologies. In June 2012, Drs. Alan Fenn and Bradley Perry joined Michael Watts, an associate professor in MIT's Department of Electrical Engineering and Computer Science, to conduct "Build a Small Radar System," and in August, the three led "Build a Small Phased Array Radar Sensor." Drs. Kevin Holman and Jane Luu collaborated in July with Prof. Jeffrey Shapiro, the Julius A. Stratton Professor of Electrical Engineering at MIT, to present "Build a Laser Radar: Design Principles, Technologies, and Applications."

## Independent Activities Period at MIT

Lincoln Laboratory technical staff developed and led five activities offered during MIT's Independent Activity Period (IAP), a four-week term spanning the January semester break. Under the IAP program, for-credit classes are available for registered MIT students, and non-credit activities are open to all members of the MIT community. IAP offerings range from academic seminars to hands-on engineering projects to artistic pursuits. The activities are, as the IAP website states, "distinguished by their variety, innovative spirit, and fusion of fun and learning."

Non-credit activities cosponsored by Lincoln Laboratory and the MIT Department of Electrical Engineering and Computer Science

### *3D Manipulation of 2D Images—*

An investigation into organizing and searching digital images by using techniques such as multiview geometry, automatic feature matching, panorama formation, and 3D reconstruction of images. Dr. Peter Cho and Alexandru Vasile led this activity.

### *Build a Holographic Recording and Reconstruction System—*

Exploration of three-dimensional sensing applications of holography across diverse domains, including crystallography, synthetic aperture radar, and near-field acoustic imaging. Participants apply concepts by preparing and capturing audio holograms, then computationally localizing sources within the observed space.

Drs. Robert Freking, Christy Cull, and Evan Cull directed this activity.

### *Build a Small Phased Array Radar System Capable of Imaging Moving Targets—*

Hands-on design, fabrication, and test of a laptop-based phased-array radar sensor capable of imaging moving targets. This activity concluded with a contest to create the most intriguing radar movie. Drs. Bradley Perry, Patrick Bell,

Alan Fenn, Jeffrey Herd, and Jonathan Paul Kitchens conducted this course.

*Build a Small Radar System Capable of Sensing Range, Doppler, and Synthetic Aperture Radar Imaging—* Construction and test of a laptop-based radar system that can form Doppler, range, and synthetic aperture radar (SAR) images. This is the second year for this activity that culminates in a contest to create the best SAR image by using the system built from a supplied kit. Drs. Bradley Perry, Alan Fenn, Jeffrey Herd, Jonathan Paul Kitchens, and Melissa Meyer led this course.

### *Open Robotics Laboratory—*

Rapid prototyping of advanced autonomous robot capabilities using open-source robotics software and inexpensive ground robots. Participants commanded their robots to trace the Lincoln Laboratory logo, follow a person, and make a map. Michael Boulet, Kenneth Cole, Nicholas Armstrong-Crews, Mark Donahue, Dr. Aaron Enes, W. Nicholas Greene, Keith Ruenheck, and John Rogers conducted this workshop.



Dr. Jon Paul Kitchens helps students modify signal processing code to improve the image quality of a phased array collection.



Participants in the Open Robotics Laboratory test the design of robotic systems.

>> *Educational Collaborations with MIT, cont.*

## Architecture Design Studio: A Contemporary Laboratory

Lincoln Laboratory served as the “client” for a graduate-level studio in MIT’s School of Architecture and Planning. In the 2011 fall semester, students in the Core III Studio were asked to develop new modes of design for a modern research laboratory. The challenge was to balance the high facility demands of the scientific work with the collaborative, social nature of research activities.

Because Lincoln Laboratory is developing plans for a new facility to accommodate its expanding portfolio of fabrication engineering, rapid prototyping, and advanced microelectronics work, it presented the studio with an opportunity to design for real-world constraints imposed by the types of work to be undertaken in the facility; by the need for state-of-the-art, purpose-built laboratory environments; by the desire for flexible space for future demands; and by the physical features of the property on which the lab will be built. The Capital

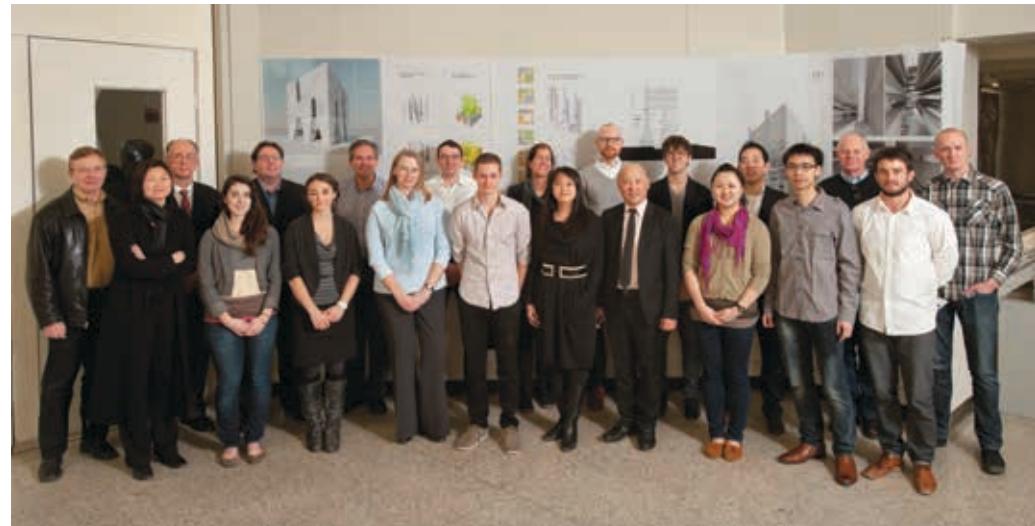


Photo by David Sella

Students whose designs were chosen for presentation at the final roundtable for the Core III Studio are shown here with Prof. Yoon (front row, 2nd from left); Andrea Brennen (front row, 3rd from left), a specialist in the Laboratory’s Wideband Tactical Networking Group and recent MIT School of Architecture alumna; Gretchen McGill (front row, 4th from left), senior program manager with the Capital Projects Office; and Dr. Robert Shin, head of the ISR and Tactical Systems Division (front row, 4th from right). In the back row, left to right, from Lincoln Laboratory are Kriss Pettersen, architect with the Capital Projects Office; Dr. George Turner, leader of the Electro-optical Materials and Devices Group; Michael Menadue, manager of the Capital Projects Office; Dr. Craig Keast, associate head of the Advanced Technology Division; Jeremy Munn, senior facilities planner from the Capital Projects Office. Also in the back row are Prof. Scott (2nd from right) and Prof. Kennedy (6th from right).

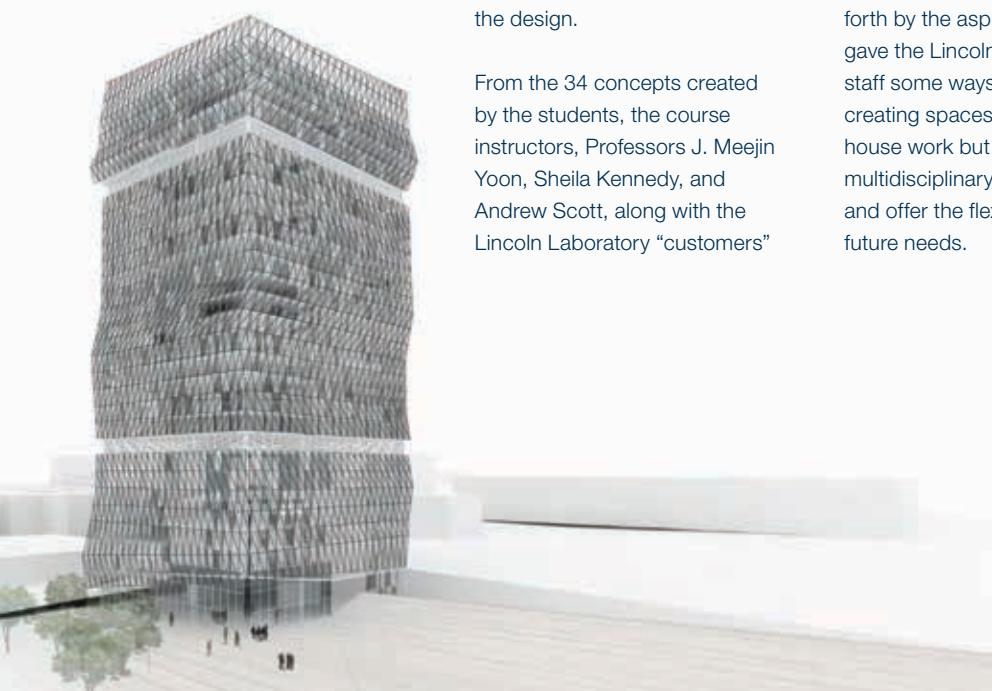
Projects Office and management from the Engineering and Advanced Technology Divisions provided studio participants with the technical, cultural, and programmatic parameters for the design.

From the 34 concepts created by the students, the course instructors, Professors J. Meejin Yoon, Sheila Kennedy, and Andrew Scott, along with the Lincoln Laboratory “customers”

chose 13 designs to critique in a post-course showcase in February 2012. While none of the students’ designs are under consideration for the actual building, the ideas set forth by the aspiring architects gave the Lincoln Laboratory staff some ways to look at creating spaces that not only house work but also promote multidisciplinary collaborations and offer the flexibility to meet future needs.



At a design review, student Juney Lee explained the choices he made in designing a modern research facility.



This rendering depicts a student’s concept for a research Laboratory that accommodates a small land space and provides variable use of natural light.

# University Programs

## Summer Research Program

Lincoln Laboratory hires undergraduate and graduate students from top universities for summer internships in technical groups. Students gain hands-on experience in a leading-edge research environment while contributing to projects that complement their courses of study. At the end of their internships, the students present the results of their research at an open forum. In 2012, 74 undergraduates and 89 graduate students from 69 different schools worked at the Laboratory.

## University Cooperative Education Students

Technical groups at Lincoln Laboratory employ students from area colleges as co-ops working full time with mentors during the summer or work/study semesters and part time during academic terms. Highly qualified students selected as co-ops become significant contributors to technical project teams. During the first semester of 2012, 41 co-ops are working in divisions and departments at the Laboratory.

## Worcester Polytechnic Institute Major Qualifying Project Program

In 2012, 12 students were accepted as Laboratory interns under the Worcester Polytechnic Institute's Major Qualifying Project Program, which requires students to complete an undergraduate project equivalent to a senior thesis. The program allows students to demonstrate the application of skills, methods, and knowledge to problems typical of those encountered in industry.

## Graduate Fellowship Program

In 2011–2012, seven students were awarded grants through this program that offers graduate fellowships to science and engineering students pursuing MS or PhD degrees at partner universities. Funds support a Fellow's stipend, supplement an assistantship, or subsidize other direct research expenses.



The 2012 class of summer interns participated on projects in a diversity of fields that included communications technologies, data analysis, software development, networking, laser systems, and radar sensors. The interns were chosen from 1300 applicants for summer positions.

# Technical Education and Workshops

## Technical Education for Staff

Lincoln Laboratory offers a variety of educational opportunities and technical training for its staff. The Graduate Education Programs enable staff members to pursue advanced degrees, and the MIT tuition assistance program helps employees finance their continuing education. Onsite courses for employees broaden technical knowledge and skills, and acquaint new staff members with the Laboratory's technology and technical themes.

## Graduate Education

### *Lincoln Scholars Program*

Currently, 28 staff members are enrolled in the Lincoln Scholars Program, a competitive program for which staff are eligible to apply and under which participants are funded by the Laboratory for full-time pursuit of an advanced degree at MIT or another local university. Lincoln Scholars contribute to the Laboratory under terms arranged with the Graduate Education Committee

and work at the Laboratory during summer breaks. Since June 2011, four staff members earned doctorates and seven earned master's degrees through the program (see sidebar below).

### *Distance Learning*

Three distance learning programs coordinated by the Graduate Education Committee allow technical staff to earn advanced degrees while continuing to work full time at the Laboratory: the Master of Science in Information Technology—Software Engineering and the Executive Master of Science in Information Assurance—Cyber Forensics and Incident Response offered by Carnegie Mellon University; and the Master of Professional Studies in Information Sciences offered by Pennsylvania State University College of Information Sciences and Technology. In September 2011, two staff members received degrees from Penn State. Currently, five people are enrolled in the Penn State program, one of whom will be awarded a degree in May 2012.

### LINCOLN SCHOLAR

## Diane Staheli: Making information more accessible

Diane Staheli is working toward a master's degree at Bentley University in a field growing more important because of the explosion in information accessed and manipulated on computers: Human Factors in Information Design. Her goal is to make the interaction between computers and their human users simpler and more intuitive. "We want to design for how people want to work," says Staheli. This challenge may involve creating computer displays that show a lot of information quickly, developing new strategies for graphically depicting data, and tapping into artificial intelligence research to configure a perceptive interface between computer and user.

Because the Lincoln Scholars program provides financial support for full-time work on advanced degrees, it allows Staheli to become immersed in this innovative field. "I have the opportunity to really concentrate on my studies," she says. "It's an intensive learning experience. As a full-time student, I have more time to focus on the coursework and less worry about how to fit classes and homework into a busy schedule."

This summer, Staheli, who is completing her first semester at Bentley this spring, will be at Lincoln Laboratory doing preliminary work to develop a thesis project. She is a member of the Technology Innovation and Integration sector of the Information Services



Department, but will be talking with staff outside her group for ideas for her project. "I am connecting with the human factors experts around the Lab. They are not centralized in any one group," she says. When she returns to the Laboratory with her new degree, she could contribute to a variety of programs, including many in technical divisions, that would benefit from well-crafted visualizations of data or improved user experiences with systems.



Twenty-four U.S. Military Academy cadets attended the one-day Defense Technology Seminar. The cadets were introduced to the Laboratory's mission as a Department of Defense Federally Funded Research and Development Center, toured the facilities, and were briefed on the Laboratory's technical contributions to national security by William Delaney, Director's Office Fellow, in center of group.

### Training in Scientific Computing

Lincoln Laboratory offers a wide range of programming courses in areas such as C++, HTML, Java, Linux, PHP, Perl, Python, UML, UNIX and XML, and a complete MATLAB curriculum that includes courses in signal processing, image processing, interfacing MATLAB with C code, and programming techniques.

The Laboratory introduced a new curriculum covering field-programmable gate array (FPGA) design, Verilog language, VHDL language, and Xilinx's PlanAhead™ Design and Analysis Tool. These courses run from one to five days.

### 2011–2012 In-house Multisession Courses

- Introduction to ISR Systems and Technology
- Optical Systems Overview
- Signal Processing on Graphs and Databases: a Detection Theory Approach to Network Science
- Satellite Laser Communications



These 14 military Fellows from all branches of the Services performed research at Lincoln Laboratory during the 2011–2012 term. Four other Fellows also participated in this program that offers officers the opportunity to contribute directly to projects related to their future assignments.

### Military Fellows Program

The Military Fellows Program supports graduate education by awarding fellowships to officers who are fulfilling requirements either for programs at senior professional military schools or for advanced degrees at MIT. Military Fellows conduct research on Laboratory-sponsored programs and provide a critical user aspect to all programs on which they work.

*Continues on page 50 >>*

>> *Technical Education and Workshops, cont.*

## Workshops and Courses

The listing of workshops and seminars hosted by Lincoln Laboratory shows the range of research that the Laboratory shares with the technical and defense communities. The workshops address technology developments in longstanding program areas, such as air vehicle survivability and ballistic missile defense, and in its newer areas of research, such as homeland protection and cyber security.

Many workshops bring in guest speakers from the defense community, industry, and academia to add their perspectives on the application of advanced technology to their fields. Most workshops draw about 300 attendees. The exception

is the Defense Technology Seminar, a week-long program of seminars and tours offered to approximately 75 invited guests from the military and government agencies.

Lincoln Laboratory also hosts a number of multi-day courses for user communities with which the Laboratory interacts. Courses for invited military officers and Department of Defense civilians enhance understanding of current research and the systems developed at the Laboratory, and are part of the Laboratory's mission to extend scientific knowledge. Technical staff also present courses at the Naval War College, Newport, Rhode Island; each semester, one course is scheduled, and the topics vary to address the college's needs.

## 2011–2012 Workshop and Course Schedule

### SEPTEMBER 2011

**20–22** High Performance Embedded Computing Workshop  
**26** Mechanical Engineering Technology Symposium  
**26–27** Subthreshold Microelectronics Conference

### OCTOBER 2011

**4–6** Intelligence, Surveillance, and Reconnaissance Workshop  
**27** Software Engineering Symposium

### NOVEMBER 2011

**8–10** Air Traffic Control Workshop

### DECEMBER 2011

**6–8** Ballistic Missile Defense Technology Course

### JANUARY 2012

**23–27** Homeland Protection Course

### FEBRUARY 2012

**21–22** Anti-tamper Policy, Technology, and Application Short Course

### MARCH 2012

**13–15** Homeland Protection Workshop  
**26–30** Defense Technology Seminar

### APRIL 2012

**10–11** Lincoln Laboratory Communications Conference

### 24–26

Technology for Intelligence, Surveillance, and Reconnaissance Course

### MAY 2012

**1–3** Space Control Conference  
**8–10** Air Vehicle Survivability Workshop  
**15–17** Air and Missile Defense Technology Workshop  
**22–24** Networking and Communications Course

### JUNE 2012

**19–21** Introduction to Radar Systems Course

### JULY 2012

**10–12** Cyber and Netcentric Workshop



This year marked the sixteenth annual Defense Technology Seminar at Lincoln Laboratory. Attendees included military officers and Department of Defense civilians. The seminar focused on the application of advanced electronics technology to critical surface, air, and space military challenges. A number of distinguished guest speakers offered insights on current national security issues.



Attendees at the Laboratory's first Homeland Protection Course are pictured with the leadership of the Homeland Protection and Air Traffic Control Division. The course provided military officers and Department of Defense civilians an overview of homeland protection technologies and concepts.

# Diversity and Inclusion

The broad range of experiences and perspectives of the staff strengthen Lincoln Laboratory's ability to develop multi-faceted, innovative approaches to problems. Fostering a work environment that supports such diversity is core to the Laboratory's continued success. Ongoing initiatives are promoting a workplace that both seeks and appreciates the diverse talents and ideas of employees.

## Lincoln Laboratory New Employee Network

The Lincoln Laboratory New Employee Network (LLNEN) helps new employees transition from their previous environments to the Laboratory and the region. By providing a social network for new employees, LLNEN promotes the retention of talented individuals. The network also encourages participation in professional development and community outreach opportunities. For example, a Habitat for Humanity "build day" has been a staple of LLNEN's community service efforts.

In February 2012, members from LLNEN presented a Science on Saturday demonstration called "Spy Science." Student attendees participated in activities that illustrated how technology is used in intelligence work. They tried their hands at encrypting and decrypting messages, disguising and identifying their voices, and detecting the location of volunteer "criminals" by using infrared imaging.

## Lincoln Laboratory Technical Women's Network

To promote the retention and achievement of women technical staff, Lincoln Laboratory Technical Women's Network (LLTWN) provides a forum for sharing strategies for success and a mentoring program that fosters career development. To acquaint staff with technology developments, monthly meetings often feature presentations by women researchers from Laboratory technical groups.

## Lincoln Laboratory Hispanic and Latino Network

Through monthly meetings, mentoring, and other activities, the Hispanic and Latino Network (LLHLN) supports educational and professional development for its members, encourages

**RIGHT:** Dr. Pedro Torres-Carrasquillo, a technical staff member in the Human Language Technology Group, was presented with the Jose Hernandez Award of MAES: Latino Scientists and Engineers. The award recognizes Torres-Carrasquillo for his "successful model of mentoring and tracking top undergraduate students from the University of Puerto Rico through prestigious graduate schools to employment" that "is now being replicated across federally recognized Hispanic Serving Institutions (HSIs) in MAES." Shown here at the 2012 Latino Science and Engineering Awards Celebration on 23 April 2012 are Torres-Carrasquillo, third from left, and Gabriela Galaviz, Christy Cull, and Edward Betancourt of the LLHLN.

involvement in community outreach activities, and fosters awareness of the rich Hispanic culture.

## Lincoln Laboratory Veterans Network

The newly established Lincoln Laboratory Veterans Network (LLVET) works with the Professional and Community Enhancement Committee (PACE) to assist veterans directly transitioning from the military to the Laboratory. LLVET supports local community outreach to U.S. troops and veterans, and keeps members informed of activities and policies that affect veterans.

## Mentorship Programs

Recognizing that strong mentorships enhance career development and improve employee retention, Lincoln Laboratory offers four mentoring programs. The New Employee Guides program focuses on acquainting newly hired employees with their groups, divisions, or departments. Volunteer "guides" provide information and resources useful to new staff members.

Employees can later choose to participate in more specialized mentoring programs:

- Early Career Mentoring provides a six-month, one-on-one mentorship to help technical and administrative professionals with early career development.
- Circle Mentoring uses small discussion groups led by experienced employees to address topics relevant to professional and career growth.
- By partnering a new assistant group leader with an experienced group leader, the New Assistant Group Leader Mentoring helps technical staff members transition into their new responsibilities.



# Awards and Recognition

## 2011 MIT Lincoln Laboratory Technical Excellence Awards



Dr. Richard P. Lippmann, for his nationally recognized leadership in developing cyber security tools and techniques, his contributions to the field of speech recognition, and his international leadership in neural networks and pattern classification.



Dr. Gary F. Hatke, for his contributions in the development of direction finding for radar guided missiles, ground-based and airborne signals intelligence, robust GPS navigation, counter-improvised explosive device systems, and special communications.

## 2011 MIT Lincoln Laboratory Early Career Technical Achievement Awards

Michael T. Boulet, for his technical abilities and vision in putting together a coherent strategy for Lincoln Laboratory's overall autonomous systems effort, and for his technical and design support to important communications programs.

Dr. Mykel J. Kochenderfer, for his development of advanced decision theoretic techniques used in systems for solving problems in air traffic control, and for work instrumental to improving air traffic safety.

## 2011 MIT Lincoln Laboratory Best Paper Award

Dr. Todd H. Rider, Christina E. Postema-Zook, Tara L. Boettcher, Scott T. Wick, Jennifer S. Pancoast, and Benjamin D. Zusman, for "Broad-Spectrum Antiviral Therapeutics," published in *PLoS ONE* in July 2011.

## 2011 MIT Lincoln Laboratory Best Invention Award, 2012 Museum of Science "Invented Here!" Award, and 2012 First-Place Berthold Leibinger Innovationspreis

Dr. Tso Yee Fan and Dr. Antonio Sanchez-Rubio of MIT Lincoln Laboratory and Dr. Bien Chann, of TeraDiode (formerly at Lincoln Laboratory), for "External-Cavity One-Dimensional Multi-wavelength Beam Combining of Two-Dimensional Laser Elements," granted a U.S. patent in November 2011. The Berthold Leibinger Foundation's international biennial Innovationspreis honors scientists who significantly advance the field of laser technology. This technology was also named a 2012 R&D 100 Award winner (see page 57).

*Continues on page 54 >>*

## Early Career Technical Achievement Awards

Michael T. Boulet, a member of the technical staff in the Control Systems Engineering Group, was recognized for his work on diverse systems. He has demonstrated technical depth and vision in the autonomous systems field and is developing a coherent strategy for the Laboratory's overall autonomous systems effort. He has designed, coded, implemented, and provided field support for an airborne laser communications terminal telemetry system, and designed the three-axis inertial stabilization and pointing system for the Laboratory's HMMWV-mounted, communications-on-the-move satellite communications terminal. A former Lincoln Scholar, he also served as the flight software engineer for the Space-based Space-surveillance Technology Insertion Next Generation (SSTING) program.



Dr. Mykel J. Kochenderfer, a member of the technical staff in the Surveillance Systems Group, was recognized for his work on advanced decision theoretic techniques that are used to develop autonomous, semi-autonomous, and decision support systems to address air traffic control problems. His work is reshaping the Federal Aviation Administration's approach toward advancing next-generation collision avoidance systems. In addition, his research is being applied in Department of Homeland Security and Department of Defense programs for developing sense-and-avoid systems for unmanned aircraft. His knowledge of artificial intelligence and machine learning is helping define concepts for an end-to-end approach for evaluating safety systems and algorithms.



>> *Awards and Recognition, cont.*

## William Delaney Elected to the National Academy of Engineering



William P. Delaney, Director's Office Fellow, was elected a member of the National Academy of Engineering (NAE). Bill was honored with membership for his "contributions to radar systems for national defense."

The NAE is an independent, nonprofit institution that provides objective, expert advice to the federal government on issues related to engineering and technology. NAE members are among the most accomplished engineers in the world and are elected on the basis of their contributions to research, engineering practices, and education, and for their leadership in pioneering technologies.

During his career at Lincoln Laboratory, Bill held management positions in missile defense, air defense, air traffic control, and battlefield surveillance, all involving radar systems. He served as Assistant Director of Lincoln Laboratory from June 1987 to July 1995. Prior to his directorship, he

served in many leadership roles: Division Head of the Surveillance and Control Division, Associate Division Head of that division, and Associate Division Head of the Radar Measurements Division.

From 1973 to 1976, on assignment to the Office of the Secretary of Defense, Bill had responsibilities for research and development in strategic defense systems. At Kwajalein Atoll, Marshall Islands, he led the ARPA-Lincoln C-band Observables Radar (ALCOR) project. In 1970, ALCOR was the first long-range radar system to generate, amplify, radiate, and process a very wide band signal. Today, ALCOR is an important national asset, contributing valuable data for ballistic missile defense research and for satellite imaging.

Bill has served on many government committees, including the Air Force Scientific Advisory Board and the Defense Science Board, of which he is a Senior Fellow. He holds a BEE degree from Rensselaer Polytechnic Institute and an SMEE degree from the Massachusetts Institute of Technology.

### MIT Lincoln Laboratory Fellows

**Dr. Don M. Boroson** and **Dr. Barry E. Burke**, named Laboratory Fellows in recognition of their technical talent and their outstanding contributions to Laboratory programs over many years.



### 2012 SPIE Fellows

**Dr. Theodore H. Fedynyshyn**, for work in photoresist materials and process technology.  
**Dr. Don M. Boroson**, for work in satellite laser communications.

### 2011 Geospatial Intelligence Achievement Award

Awarded by the U.S. Geospatial Intelligence Foundation to the National Geospatial-Intelligence Agency's LIDAR team, which included **Ross W. Anderson**, **Brandon R. Call**, **Dr. Dale G. Fried**, **Dennis R. Hall**, **Dr. Richard Heinrichs**, **Robert C. Knowlton**, and **Christopher W. Reichert** from MIT Lincoln Laboratory's Airborne Radar Imaging Research Testbed (ALIRT) program.

### IEEE MICRORAD 2012 Best Poster Award

**Dr. William J. Blackwell**, **Dr. Christopher J. Galbraith**, **Dr. Timothy M. Hancock**, **Dr. Vincent R. Leslie**, **Dr. Idahosa A. Osaretin**, and **Michael W. Shields** of Lincoln Laboratory, and **Dr. Paul Racette** and **Lawrence Hilliard** of the NASA Goddard Space Center were awarded Best of Conference Poster for "Design and Analysis of a Hyperspectral Microwave Receiver Subsystem," which was presented at the 2012 IEEE 12th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment (MICRORAD).

### MILCOM 2011 Best Paper Award

**Christopher G. Sacca**, for co-authorship of a paper on advances in cyber experiment automation that was named best paper in its category at the 2011 MILCOM (Military Communications) Conference. Other authors came from the Air Force Research Laboratory and Lockheed Martin.

### Best Paper Award—2011 IEEE International Conference on Technologies for Homeland Security

**Dr. Jason R. Thornton**, **Dr. Michael T. Chan**, **Dr. Heather Zwahlen**, and former staff members **Jeanette Baran-Gale** and **Daniel Butler**, for the paper "Person Attribute Search for Large-Area Video Surveillance."

### 2012–2014 GEM Consortium President

**Dr. Eric D. Evans**, confirmed as President of the National Graduate Degrees for Minorities in Engineering and Science (GEM) Consortium for 2012–2014. GEM's mission is to promote the participation of underrepresented groups in post-graduate science and engineering educational and professional endeavors.

### 2012 Distinguished Alumnus Award

**Dr. Eric D. Evans** was honored with a 2012 Distinguished Alumnus Award by the College of Engineering at The Ohio State University, for his professional achievements and leadership.

### IEEE Milestone in Electrical Engineering and Computing

The development of the **Semi-Automatic Ground Environment (SAGE)** system was named an IEEE Milestone in recognition

## LINCOLN LABORATORY CONGRATULATES JANE LUU *Recipient of 2012 Kavli and Shaw Prizes*

Dr. Jane Luu, a technical staff member in the Active Optical Systems Group, is a co-recipient of the 2012 Shaw Prize in Astronomy and the 2012 Kavli Prize in Astrophysics. The awards are for the discovery and characterization of objects in the Kuiper Belt, a region beyond Neptune's orbit.

Dr. Luu was a postdoctoral researcher at the Harvard Smithsonian Center for Astrophysics in Cambridge when she and Prof. David Jewitt detected the first trans-Neptunian object during a search of the solar system in 1992. The discovery, made with the University of Hawaii's telescope on Mauna Kea, was the culmination of five years of searching for an elusive proof that the outer solar system was not empty space.

The Shaw Prize was awarded to Drs. Luu and Jewitt, while the Kavli Prize also included Michael E. Brown of the California Institute of Technology, who built on Luu and Jewitt's work to extend the world's understanding of the outer solar system.

Dr. Luu and fellow recipients received their prizes at ceremonies this fall. On 4 September, at a ceremony held in Oslo, King Harald of Norway presented the Kavli Prizes. On 17 September in Hong Kong, the Honorable C.Y. Leung, chief executive of the Hong Kong Special Administrative Region of the People's Republic of China, presented the Shaw Prizes.

The Shaw Prize is an international award that honors individuals who have made outstanding contributions to their fields. The prize consists of three annual awards—one each in astronomy, life science and medicine, and mathematical sciences. The Shaw prize, established in 2002, is administered by the Hong Kong-based Shaw Prize Foundation, which supports education, scientific research, medical and human welfare services, and culture. The biennial Kavli Prize recognizes scientists from around the world for seminal advances in three research areas: astrophysics, nanoscience, and neuroscience. It is a partnership between the Norwegian Academy of Science and Letters, the Kavli Foundation in the U.S., and the Norwegian Ministry of Education and Research.



Erlend Aas/Sampx

The winners of the 2012 Kavli Prize in Astrophysics are, left to right, David Jewitt of the University of California—Los Angeles; Jane Luu of MIT Lincoln Laboratory; and Michael Brown of the California Institute of Technology.



Jane Luu receives her 2012 Shaw Prize from the Honorable C.Y. Leung.

of the system's contribution to the air defense of the United States and its innovations in digital computing. The commemorative plaque for this milestone was placed at Lincoln Laboratory. IEEE Milestones honor technological advances that benefit humanity.

### NASA Space Communications and Navigation

#### Achievement Award

Dr. Bryan S. Robinson, for his outstanding work on the Lunar Laser Communications Demonstration project.

### U.S. Army Achievement Medal for Civilian Service

Dr. Wade M. Kornegay, for outstanding service as a member of the Army Science Board from 2004 to 2011.

### IEEE Managerial Excellence in an Engineering Organization Award

Dr. William J. Blackwell, presented by IEEE Region I "for outstanding leadership of the multidisciplinary technical team developing innovative future microwave remote sensing systems."

*Continues on page 56 >>*

>> *Awards and Recognition, cont.*

### Aegis Ballistic Missile Defense Excellence Award

The award and an Aegis Ballistic Missile Defense (BMD) flag were presented to Lincoln Laboratory for significant contributions to the Aegis BMD program.

### 2011 Superior Security Rating

To Lincoln Laboratory's collateral security program from the U.S. Air Force 66th Air Base Wing Information Protection Office.



Rear Admiral Joseph Horn, U.S. Navy, left, presents Director Eric Evans with an Aegis Ballistic Missile Defense flag and citation to recognize Lincoln Laboratory's contributions to the Aegis BMD program.

### Army Certificate of Appreciation for Patriotic Civilian Service

Joanne Knoll, for "exceptionally dedicated and caring service to the 1st Battalion, 17th Field Artillery Regiment."

### 2012 MIT Excellence Awards

*Unsung Hero Awards*—Sam Stambler and Michael F. Crones.

*Bringing Out the Best Award*—Lincoln Laboratory 60th Anniversary Planning Committee: Leslie Weiner Alger, Michele R. Andriolo, Gerald C. Augeri, Ellen B. Beachy, Mark E. Bury, Heather E. Clark, Richard P. Gabriele, Dr. Pascale M. Gouker, David R. Granchelli, Alan A. Grometstein, Christopher B. Johnson, Dr. William E. Keicher, Alicia A. LaDuke, Dr. Kenneth R. Roth, Dorothy S. Ryan, Karen J. Springfield, Derek B. Varga, Cynthia J. Wallace, Dennis P. Weron, and Roslyn R. Wesley.

### 2012 American Inhouse Design Awards

Awarded by Graphic Design USA to MIT Lincoln Laboratory's Communications and Community Outreach Office for the design of the following publications and products: *MIT Lincoln Laboratory: Technology in Support of National Security* (the new history book); *60 Innovations Over 60 Years* (booklet); MIT Next Century Convocation Posters; 60th Anniversary Website; *Kwajalein 50th Anniversary Booklet*; and *Giving Program Brochure*.



The Lincoln Laboratory 60th Anniversary Planning Team was honored with a 2012 MIT Excellence Award. The team includes the following members: back row, left to right, David Granchelli, William Keicher, Christopher Johnson, and Karen Springfield; 3rd row back, left to right, Pascale Gouker, Heather Clark, Alicia LaDuke, Dorothy Ryan, Alan Grometstein, Leslie Alger, and Richard Gabriele; 2nd row back, left to right, Michele Andriolo, Gerald Augeri, Derek Varga, Cynthia Wallace, Ellen Beachy, and Mark Bury. Roslyn Wesley of the team is in the front row with, left to right, Dr. Eric Evans, Director, MIT Lincoln Laboratory; Israel Ruiz, Executive Vice President and Treasurer, MIT; Dr. L. Rafael Reif, President, MIT; Dr. Alison Alden, Vice President for Human Resources, MIT; and Chris Colombo, Dean for Student Life, MIT.

# R&D 100 Awards



Four technologies developed at MIT Lincoln Laboratory were named 2012 recipients of R&D 100 Awards. Given annually by *R&D Magazine*, an international journal for research scientists and engineers, these awards have for 50 years recognized the 100 most technologically significant innovations introduced during the prior year. Recipients of R&D 100 Awards are chosen from hundreds of nominations by a panel of independent evaluators and editors of *R&D Magazine*. The awardees represent a broad range of technologies developed by industrial enterprises, government laboratories, and university research facilities from around the world.

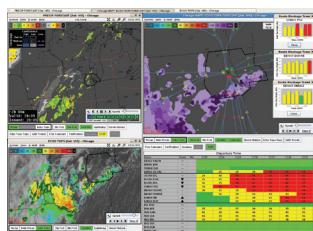


At the R&D 100 Awards banquet in Orlando, Florida, on 1 November, members of the teams that won 2012 awards accepted commemorative plaques. Pictured here with Director Eric Evans (at left), are, left to right, Richard Lambour, Walter Bastow, Ronak Shah, Roger Khazan, Dan Utin, Anthony Smith, Eric Pearce, Kevin Creedon, Anish Goyal, James Gregory, Bradley Crowe, Richard Ferris, Kirk MacKenzie, Richard DeLaura, and John Hayward.

## Lincoln Open Cryptographic Key Management Architecture

A highly portable software library that solves the complex problem of cryptographic key management, thereby enabling broad employment of cryptographic protections in devices

Team: Dr. Roger Khazan, Dan Utin, Adam Petcher, Dr. Jonathan Herzog, Sean O'Melia, Dr. Robert Cunningham, Walter Bastow, Raymond Govotski, and Mark Yeager (formerly of Lincoln Laboratory)



## Route Availability Planning Tool

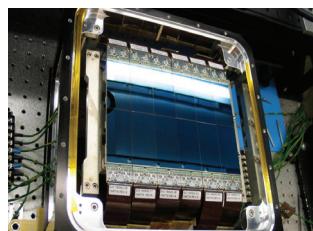
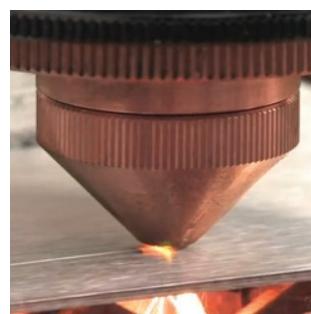
An automated decision support tool that predicts availability of aircraft departure routes during thunderstorms in terminal and adjacent en route airspace

TEAM: Richard DeLaura, Ngaire Underhill, John Hayward, Kirk MacKenzie, Bradley Crowe, Richard Ferris, and Russell Todd; Michael Robinson, Nic Yaros, Shawn Allan, Dale Rhoda, and Beth Kocab (formerly of Lincoln Laboratory); Leo Prusak, Tom Kelly, and Ralph Tamburro (from the FAA), and Tom White (formerly FAA)

## Wavelength Beam-Combining Fiber-Coupled Diode Laser

A high-intensity diode laser that provides an efficient and reliable, low-cost, high-power source for welding and cutting metals

TEAM: Dr. Antonio Sanchez-Rubio, Dr. Tso Yee Fan, Dr. Steven Augst, Kevin Creedon, Dr. Anish Goyal; Julie Gopinath and Vincenzo Daneu (formerly of Lincoln Laboratory); and Dr. Bien Chann and Dr. Robin Huang of TeraDiode



## Wide Field-of-View Curved Focal Plane Array

A curved charge-coupled device (CCD) that corrects for the inherent aberrations of mirrors and lenses, thus enabling wide field-of-view surveillance

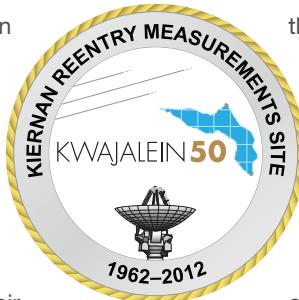
TEAM: Dr. Eric Pearce, Dr. James Gregory, Dr. Barry Burke, Harry Clark, Bradley Felton, David Fisch, Keith Warner, Dr. Richard Lambour, Dr. Ronak Shah, Donald Johnson, James Sopchak, Anthony Smith, Edward Boughan (consultant); Linda Mendenhall and Richard Osgood (formerly of Lincoln Laboratory); and Gerald Luppino of GL Scientific

# Kiernan Reentry Measurements Site

## *Fifty Years of Service: 1962–2012*

To recognize this 50th anniversary, a special celebration was held at the Kwajalein Atoll on 12 and 13 February 2012. U.S. government officials, Lincoln Laboratory Kwajalein alumni from the early 1960s and their family members, and current Laboratory leadership attended the celebration events and spent five days on the island.

For most visitors, the anniversary event began with their arrival on Saturday morning, 11 February. After checking into their living quarters, they attended an Orientation Luncheon at which they renewed acquaintances and met fellow attendees and the on-island Army and Lincoln Laboratory leadership. Colonel Joseph Gaines, the U.S. Army Kwajalein Atoll (USAKA) Commander, briefed the guests on USAKA operations. Everyone



then enjoyed an island bus tour narrated by Kurt Schwan, the Lincoln Laboratory site manager.

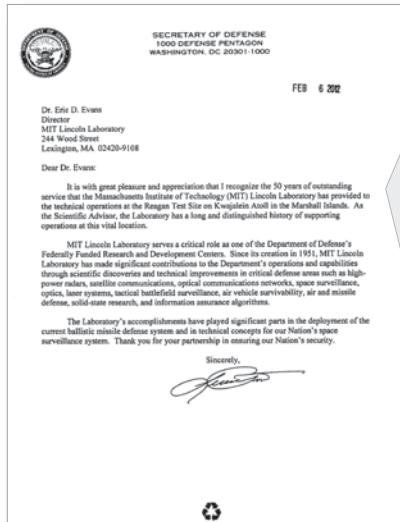
Under perfect island weather conditions, a barbecue dinner at Emon Beach, hosted by Kurt and Penny Schwan, ended the day.

Since Sunday was a day free of work responsibilities for most visitors, they took advantage of the various recreational activities available at

Kwajalein, including a sailing and snorkeling trip to Bigej on a privately owned yacht, scuba diving in the crystal clear waters of the lagoon, a deep-sea fishing excursion (on which no fish were caught!), a trip to the neighboring island of Ebeye, and a round of golf for the land-lovers.



CLOCKWISE FROM TOP: Alumni and families arriving at Kwajalein; Martha Campbell, U.S. Ambassador to the Republic of the Marshall Islands, speaking with Dr. Hsiao-hua Burke, Division Head, Air and Missile Defense Technology, Lincoln Laboratory; attendees enjoying golf on Sunday; dance troop performing at the 50th Anniversary dinner.



*"It is with great pleasure and appreciation that I recognize the 50 years of outstanding service that the Massachusetts Institute of Technology (MIT) Lincoln Laboratory has provided to the technical operations at the Reagan test site on Kwajalein Atoll in the Marshall Islands. As the Scientific Advisor, the Laboratory has a long and distinguished history of supporting operations at this vital location.*

Zachary Lemnios, Assistant Secretary of Defense for Research and Engineering, was a keynote speaker at the commemorative ceremony. He presented Lincoln Laboratory with a congratulatory letter (right) from Secretary of Defense Leon Panetta.

In the evening, a 50th Anniversary Dinner Dance, hosted by the Laboratory, was held at the Davye Davis Multi-Purpose Room, beautifully decorated around an island theme. About 100 people attended the dinner, during which they were entertained by an on-island Polynesian band and a local dance troop performing traditional hulas. Later in the evening, a disc jockey took over, and the guests filled the dance floor.

The major anniversary recognition event was held on Monday at Roi-Namur. Morning fixed-wing and helicopter flights brought 25 off-island visitors and about 25 Kwajalein residents, including all of the Laboratory's resident staff, to Roi-Namur. The day's agenda included a historical tour of the island, a tour of the KREMS radars, a group photo session at TRADEX, and lunch at the picturesque Roi Scuba Shack on the lagoon.

The highlight of the day was the 50th anniversary commemorative ceremony at the Tradewinds Theater. Dr. Eric Evans hosted this ceremony, welcoming the distinguished speakers—Martha Campbell, U.S. Ambassador to the Republic of the Marshall Islands; Zachary Lemnios, Assistant Secretary of Defense for Research and Engineering; and Debra Wymer, Director of the Space and Missile Defense Command's Technical Center—as well as other honored guests and Kwajalein alumni. Dr. Evans concluded the event by presenting Colonel Gaines with a plaque from Lincoln Laboratory to USAKA commemorating 50 years of service.

## Guest List

**Honorable Martha Campbell, U.S. Ambassador to the Republic of the Marshall Islands, and her husband Arnold**

**Honorable Zachary Lemnios, Assistant Secretary of Defense for Research and Engineering, and his military aide Colonel Brian Bedell**

**Ms. Debra Wymer, Director of U.S. Army Space and Missile Defense Command's Technical Center**

**Dr. Eric Evans, Director of MIT Lincoln Laboratory**

**Dr. Hsiao-hua Burke, Head of the Air and Missile Defense Technology Division, MIT Lincoln Laboratory**

**Dr. Kenneth Roth, MIT Lincoln Laboratory Division Fellow and Kwaj alumnus**

**Mr. Stephan Rejto, Assistant Head of the Communication Systems & Cyber Security Division, MIT Lincoln Laboratory, and Kwaj alumnus**

**Mr. Conrad Grant, Johns Hopkins University Applied Physics Laboratory**

**Mr. John Slaybaugh, MITRE Corporation**

### *Kwaj Alumni from the 1960s*

**Kent Kresa**

**Larry Lynn and wife Shirley**

**Richard Wishner and wife Susan**

**Robert Yost, wife Leah, and daughter Catherine Nagle**

**Roy Cummings, wife Leora, daughter Lauren Miller and her significant other, Brent Twyson**

**Nancy Hubert, wife of deceased Kwaj alumnus Ron Hubert, and daughter Janet Hubert**





## EDUCATIONAL AND COMMUNITY OUTREACH

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# Educational Outreach

*Outreach programs are an important component of the Laboratory's mission. Our outreach initiatives are inspired by employee desires to motivate student interest in science, technology, engineering, and math (STEM). New efforts this year include competition in the CyberPatriot Program, a STEM-based summer camp on how to build radar systems, and installation of an exhibit in the Museum of Science.*



## Classroom Presentations

Each year, Lincoln Laboratory technical staff members give free classroom presentations and lead hands-on activities to approximately 7000 students. Over 40 presentations are available in scientific fields and can be adapted for different grade levels. The Classroom Presentations program also maintains a website for "Ask the Scientist," which receives science-related questions from around the world and features an answer of the month. Volunteers in this program help prepare science kits with more than 60 do-it-yourself experiments.

## Team America Rocketry Challenge 2012

Team America Rocketry Challenge (TARC), an aerospace design and engineering event for students in grades 7–12, is run by the National Association of Rocketry and the Aerospace Industries Association. The goal of TARC is to motivate students to pursue aerospace as a career field. Curtis Heisey of the Surveillance Systems Group and Francesca Lettang of the Active Optical



Systems Group coached a five-member team called Green Eggs and Bam. The team's rocket reached an altitude of 867 feet with a flight time of 47.6 seconds, turning in a score of 68.69, a perfect score being zero. The team was one of 700 teams nationwide in the final challenge.

ABOVE: Charles Wynn of the Chemical Sensing and Synthetic Materials Group demonstrated the properties of light and color to 4th graders at Swallow Union School in Dunstable, Massachusetts.

*Continues on page 64 >>*

## EXHIBIT OPENS AT MUSEUM OF SCIENCE

Early this year, a new partnership with the Museum of Science in Boston resulted in a Laboratory-designed exhibit featured at the museum—a first for the Laboratory. The exhibit, entitled "A Song in Your Pocket," offers visitors the chance to learn about sampling music for an MP3 player and choosing between the number of songs or quality of songs, helping visitors understand the trade-off between the two. This exhibit, which opened in February, helped forge a partnership that will inspire future outreach opportunities.



## NEW RADAR SUMMER WORKSHOP

Lincoln Laboratory's first summer engineering workshop for high-school students, Lincoln Laboratory Radar Introduction for Student Engineers (LLRISE), debuted in July. The radar technology program was based on a very popular three-week class offered by Laboratory technical staff to MIT undergraduates during the January intersession between academic semesters.

The college course was modified to suit high-school students, yet provide the same depth of material and hands-on activities. While designed to provide an understanding of radar systems, the program is intended to foster a realization that engineering is about problem solving and applying knowledge in innovative ways. The two-week residential, project-based enrichment program was offered to outstanding students currently in their junior year in Boston, Cambridge, Lawrence, and Lowell high schools. Participants were challenged to build a Doppler and range radar by using creative problem-solving strategies while working in a state-of-the-art laboratory with highly talented scientists and engineers, and sampled dorm life at MIT.

Chiamaka Agbasi-Porter of the Communications and Community Outreach Office coordinated the program and was supported by nine technical staff members: Mabel Ramirez, Nestor Lopez, Shakti Davis, Raoul Ouedraogo, Shelley Scruggs, Wingyan Beverly Lykins, Gregory Ciccarelli, Bradley Perry, and Alan Fenn.

During the two-week period, the 12 high-school seniors attended college-level classes on physics, electromagnetics, mechanics of Doppler radar, modular radio-frequency design circuitry, Matlab, pulse compression, signal processing, and antennas. In addition to a presentation about career exploration, the students were given an overview of Lincoln Laboratory and a tour of its facilities, including the Flight Facility, the Antenna Test Range, and the Haystack Observatory in Westford, Massachusetts.



In between instructional lectures and homework, the students toured MIT campus and the MIT Museum, and visited MIT's Financial Aid Office to learn about the college application process. The participants also received instruction on how to stage an experiment and how to present a project, preparing them for the final technology demonstrations scheduled for the end of the two-week period. A few social activities, such as a movie night and a Boston Harbor cruise, provided breaks from the rigorous workload.

Because of the overwhelming success of this year's program, Lincoln Laboratory intends to open eligibility for future summer workshops to the entire New England region, eventually doubling the number of students participating in the event.

>> *Educational Outreach, cont.*

## Volunteers for Science Fairs and Competitions

Lincoln Laboratory supports the community by offering volunteer judges for local and state science fairs. In 2012, the Laboratory sent 12 volunteers to the Lexington High School Science Fair, six volunteers to judge the Carlisle Middle School Science Fair, one volunteer to help kids understand rocketry principles for Hanscom Air Force Base's Primary School Science Share Fair, and 13 judges to the Massachusetts State Science and Engineering Fair. Lincoln Laboratory members of the Society of Women Engineers and Robotics Outreach at Lincoln Laboratory volunteered to man booths at the Cambridge Science Festival. For the first time, the Laboratory offered a volunteer judge for the Real World Design Challenge, an annual competition that provides high-school students the opportunity to work on engineering challenges in a team environment. Each year, student teams are asked to address a challenge that confronts our nation's leading industries. This year, Phillip Evans of the Engineering Analysis and Testing Group volunteered as a judge at the state and the national competitions. Lincoln Laboratory also joined Hanscom Air Force Base's STARBASE Program, which aims to motivate fifth graders to explore science, technology, engineering, and math through an inquiry-based curriculum, hands-on activities, classroom visits from military and scientific personnel, and onsite tours in technological environments.



Laboratory staff members serve as judges at the Lexington High School Science Fair.

## Science on Saturday

New demonstrations on radar, spy science, radio astronomy and paleontology were added to the ever-popular Science on Saturday series. The spy science show investigated technologies needed to complete a mission, such as voice recognition, detection and tracking, and cryptography. The radar demonstration described how radar can predict weather, fly an airplane, and test the speed of a baseball pitch.

## Student Internships

Lincoln Laboratory arranges summer internship opportunities for graduating high-school seniors interested in science, technology, engineering, or math (STEM) careers. Three students were selected to work at Lincoln Laboratory through the Armed Forces Communications and Electronics Association Program. Each year, two students from the Minuteman Regional High School in Lexington, Massachusetts, and one student from Shawsheen Technical Vocational High School are provided with internships at Lincoln Laboratory, giving them hands-on experience in a real-world setting. Lincoln Laboratory is pleased to have been named the 2012 Internship Employer of the Year by Stevens Institute of Technology.

## John D. O'Bryant School of Math and Science Partnership

Students of the O'Bryant School in Roxbury, Massachusetts, visit the Laboratory twice a year to tour the facility and learn about career options in math and science.

## MIT Office of Engineering Outreach Programs (OEOP)

Lincoln Laboratory plays a part in four OEOP programs. For each program, the Laboratory hosts facility tours and presentations on career choices. The Minority Introduction to Engineering and Science (MITES) program is a six-week summer program for top high-school students in the nation. The Laboratory sponsors two students in the program, and hosts 75 students for a facility tour. The Saturday Engineering and Enrichment Discovery (SEED) Academy is a seven-semester technical career-exploration program for promising

students in underserved high schools. The MIT Science of Baseball Program (MSBP) is a four-week program for eighth grade boys from Boston, Lawrence, and Cambridge, Massachusetts. The Laboratory sponsors one child in this program and challenges all the boys to a softball game. The STEM program offers year-round academic enrichment for middle-school students in underserved communities. Lincoln Laboratory sponsors a robotics course and presents a Science on Saturday demonstration for STEM participants.

### Partnerships with the Society of Women Engineers

Last year, Lincoln Laboratory began a partnership with the Boston Chapter of the Society of Women Engineers. Volunteers from both organizations host a variety of activity-based demonstrations at the Laboratory throughout the year, such as Space Night, a visit with Cady Coleman: Astronaut, a robotics course, and the very popular Wow! That's Engineering! At the most recent Wow! That's Engineering! event, girls in sixth through eighth grade discovered reverse engineering; the properties



Yari Rodriguez explains how the “do-it-yourself” weather station adjusts according to atmospheric changes.

*“At first, I thought the day was going to be all lecture, like school, but it turned out to be so much fun!”*

—Participant in Wow! That's Engineering

of light; precision assembly; the relationship between weather data and weather changes; and the relationships of liquids and gases to different volumes and temperatures. The stations proved to be both educational and entertaining, best exemplified by a student who said, “At first, I thought the day was going to be all lecture, like school, but it turned out to be so much fun!”

### First-Time Finalists in CyberPatriot Competition



Lincoln Laboratory's first CyberPatriot team, Donut Hack Us, was photographed at the National Finals Competition in Washington, D.C.

The five high-school students on the Lincoln Laboratory team competed in the national championship round of CyberPatriot, a unique competition that motivates teenagers to be the nation's next cyber defenders. The students learned how to defend a simulated corporate network from external hostile attacks. The team detected and corrected categories of vulnerabilities, including policy management, vulnerability management, patch management, configuration management, and third-party management. More than 1000 teams began in the first round of competitions nationwide.

Mentored by Michael Chaplin of the Facility Services Department, Robert Cunningham of the Cyber Systems and Technology Group, Joseph Werther of the Cyber System Assessments Group, and Chiamaka Agbasi-Porter of the Communications and Community Outreach Office, this first-year team became one of 12 finalists chosen for the national competition. With help from the Paul Revere Chapter of the Air Force Association, the team received an all-expenses-paid trip to the National Finals Competition in Washington, D.C. For placing as a finalist, the team received congratulatory letters from Governor Deval Patrick and from Congressman Edward Markey.

# Robotics Outreach

## Roboworkshop

Robotics Outreach at Lincoln Laboratory (ROLL) debuted a workshop exploring the physics of NASCAR motorsports by using 1:10-scale radio-controlled cars. Middle- and high-school students learned to optimize performance of their model cars. Follow-on workshops are planned in which students will learn to program general-purpose processors to control sensors for an autonomous robotic car.

## E2@MIT

Lincoln Laboratory conducted a short robotics course as part of the curriculum for E2 (Engineering Experience) @MIT, a one-week, residential, summer program offered by MIT's Office of Engineering Outreach Programs to high-school students entering their senior year. Students in E2@MIT completed a project course in an engineering field, attended admissions and financial aid sessions, and toured labs. They were exposed to a demanding academic environment and developed the skills necessary to achieve success in science and engineering. The students were introduced to microcontroller programming and reading and generating analog signals so that they could design and develop a mobile robot platform capable of autonomous or controlled operation. The teacher of this course was assisted by Sam Stambler, Joshua Manore, and Theodore Tzanatos of the Tactical Defense Systems Group. Michael Boulet of the Control Systems Engineering Group offered a robotics demonstration during the students' tour of the Laboratory. Sam Stambler had assisted teaching an earlier robotics summer camp for high-school students, who learned how to build radio-controlled and autonomous robots. In addition, he gave a presentation about rapid prototyping to students in this camp.

## FIRST Robotics

In the FIRST (For Inspiration and Recognition of Science and Technology) Technical Challenge for older high-school students, Team 3590 qualified 2nd in the Connecticut finals, and 9th in Massachusetts

finals. They also received the Promote Award, given to the team that is most successful in creating a compelling public video message designed to change our culture and celebrate science, technology, engineering, and math. Team 2875 participated in both state finals as well.

In addition to mentoring 90 children in Lincoln Laboratory-affiliated teams, ROLL began partnerships with many sister teams for FIRST robotic



The John D. O'Bryant School robotics team participated at the state finals competition.

challenges. ROLL has a continuing collaboration with the John D. O'Bryant School in Roxbury, Massachusetts, mentoring two teams for robotics competition. ROLL also supports sister teams in Waltham, Lexington, Weston, and Shrewsbury, Massachusetts, and at Hanscom Air Force Base. A sign of the level of support of Laboratory volunteers is the fact that two mentors, John Peabody of the Aerospace Sensor Technology Group and Loretta Bessette of the ISR Systems and Architectures Group, became affiliate partners with Massachusetts FIRST Technical Challenge. As such, they hosted information nights, unveiled and explained this year's challenge for all Massachusetts FTC teams, and supported scrimmages and tournaments.

ROLL ensures that its FIRST teams have adequate supplies, funds, and mentorship to design, build, and program their robots. The Laboratory teams assist their sister teams by staging scrimmages and by sharing design concepts and programming tips.

# Community Giving

## Food Drive

The Lincoln Laboratory Hispanic and Latino Network (LLHLN) sponsored a food drive for the American Red Cross and the Boston Food Pantry in early 2012. LLHLN volunteers collected 10 bags of groceries and also volunteered at the food pantry to prepare bags of food, help carry groceries, distribute bags of potatoes, and even translate for Spanish-speaking food pantry clients.

## Veterans Support

The Lincoln Laboratory Veterans Network (LLVET) supported local veterans through fund-raising efforts. Shortly after formation, LLVET participated in a Veterans' Day fun run sponsored by the Veterans' Hospital in Bedford, Massachusetts. In May, they entered a team in the annual Run-Walk to Home event featuring a finish line at home plate in Fenway Park. This event helps provide clinical care for veterans with combat stress or traumatic brain injury, support services and counseling for wounded vets' families, research into improving treatments and preventing injuries that affect as many as 30% of troops returning home from Iraq and Afghanistan.

## Troop Support

Lincoln Laboratory's Troop Support Program sends more than 200 care packages a year to U.S. troops stationed abroad. The Laboratory's Heriberto Garcia, Michael Hanssen, Stacey Caplette, and Jared Hart are currently serving or have served overseas earlier this year. Hart said, "Getting these care



Members of the Hispanic and Latino Network volunteered at the Boston Food Pantry.

packages brings a little 'piece of home' to us. I am a Lincoln Lab employee, so to receive these care packages from the people I work with makes it all that much more special." Hart's wife, Katherine, also works at the Laboratory and manages the Troop Support Program in her free time.

## Habitat for Humanity

Lincoln Laboratory's New Employee Network supported Habitat for Humanity by building an affordable house for a needy family in the area. Twenty-four individuals joined together to hang drywall and to spackle, prime, and paint walls. They also hung siding and installed doors and insulation.



Heriberto Garcia, lower right, was on leave from the BMDS Integration Group to serve with U.S. Air Force Central Command.





## GOVERNANCE AND ORGANIZATION

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# Laboratory Governance and Organization

**MIT**  
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President

Dr. Chris A. Kaiser  
Provost

Dr. Claude R. Canizares  
Vice President

## DoD Joint Advisory Committee

Annually reviews the Laboratory's proposal for programs to be undertaken in the subsequent fiscal year and five-year plan.

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Principal Deputy, Assistant Secretary of Defense for Research and Engineering

**Ms. Betty J. Sapp**  
Director, National Reconnaissance Office

**Dr. Arati Prabhakar**  
Director, Defense Advanced Research Projects Agency

**Vice Admiral James D. Syring**  
Director, Missile Defense Agency

**Ms. Heidi Shyu**  
Assistant Secretary of the Army for Acquisition, Logistics and Technology

**Mr. Sean J. Stackley**  
Assistant Secretary of the Navy for Research, Development and Acquisition

**TBD**  
Assistant Secretary of the Air Force for Acquisition

**Maj Gen William N. McCasland**  
Commander, Air Force Research Laboratory, Joint Advisory Committee Executive Group—Chair

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Bernadette Johnson <i>Chief Technology Officer</i>	Deborah A. Valley <i>Safety, Mission Assurance, and Program Support Office</i>
David R. Granchelli <i>Communications and Community Outreach Office</i>	J. Michael Menadue <i>Capital Projects Office</i>

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Marc D. Bernstein <i>Associate Director</i>	

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Gerald C. Augeri <i>Assistant Head</i>	Stephan B. Rejto <i>Assistant Head</i>
Dennis J. Keane <i>Assistant Head</i>	Marc A. Zissman <i>Assistant Head</i>

**Communication Systems and Cyber Security**

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James M. Flavin <i>Assistant Head</i>	William R. Davis, Jr. <i>Assistant Head</i>
Mark E. Weber <i>Assistant Head</i>	Michael T. Languirand <i>Assistant Head</i>

**Advanced Technology**

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	Simon Verghese <i>Assistant Head</i>

**Intelligence, Surveillance, and Reconnaissance and Tactical Systems**

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Curtis W. Davis III <i>Assistant Head</i>	James Ward <i>Assistant Head</i>

**Homeland Protection and Air Traffic Control**

Israel Soibelman <i>Head</i>	Eliahu H. Niewood <i>Head</i>
James M. Flavin <i>Assistant Head</i>	William R. Davis, Jr. <i>Assistant Head</i>
Mark E. Weber <i>Assistant Head</i>	Michael T. Languirand <i>Assistant Head</i>

**Engineering**

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	Craig E. Perini <i>Assistant Head</i>

**Aerospace**

Grant H. Stokes <i>Head</i>	Lawrence M. Candell <i>Assistant Head</i>
	Craig E. Perini <i>Assistant Head</i>

## MIT Lincoln Laboratory Advisory Board

Appointed by the MIT President and reports to the Provost. The Advisory Board meets twice a year to review the direction of Laboratory programs.



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Grumman



**ADM Edmund P.  
Giambastiani Jr.,  
USN (Ret)**  
Former Vice-Chairman of  
the Joint Chiefs of Staff



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USAF (Ret)**  
Board of Directors,  
General Dynamics  
Corporation; Former  
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Materials Science  
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Massachusetts Institute  
of Technology



**Prof. Daniel E.  
Hastings**  
Dean of Undergraduate  
Education, Massachusetts  
Institute of Technology;  
Former Chief Scientist  
of the Air Force



**Prof. Hans Mark**  
The University of Texas  
at Austin; Former  
Secretary of the Air  
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Co-CEO, Stone Key  
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Foreign Intelligence  
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Reconnaissance Office

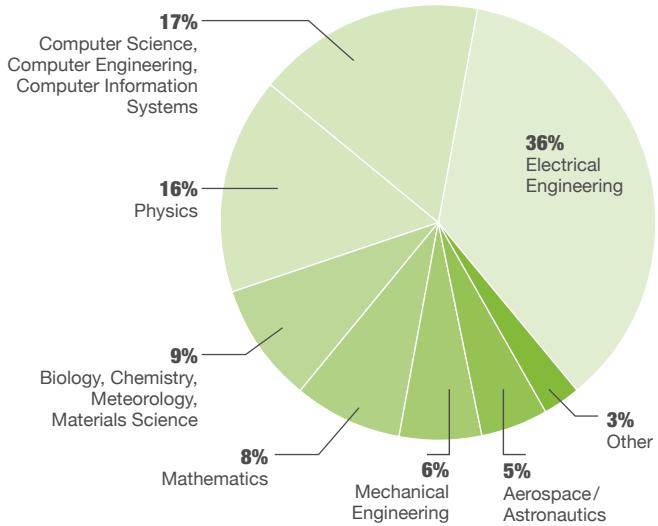


**GEN Gordon R.  
Sullivan, USA (Ret)**  
President of the  
Association of the  
U.S. Army; Former Chief  
of Staff of the U.S. Army

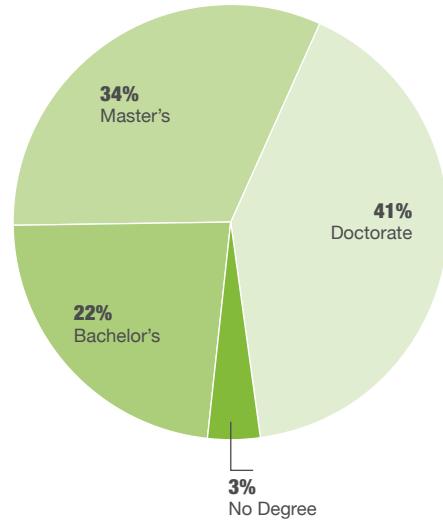
# Staff and Laboratory Programs

## Composition of Professional Technical Staff

### Academic Discipline

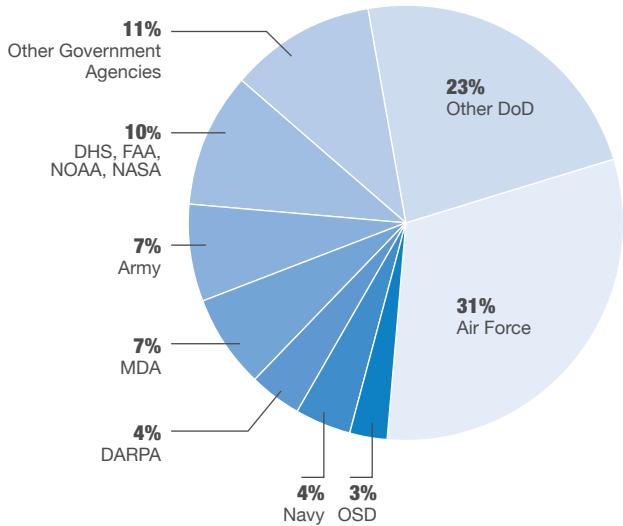


### Academic Degree

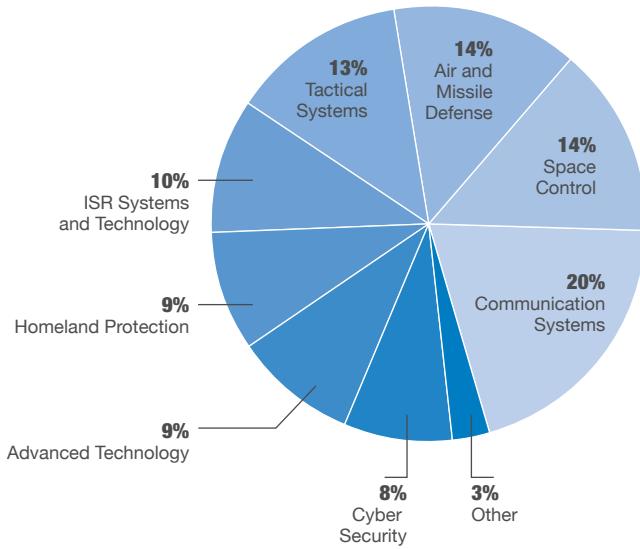


## Breakdown of Laboratory Program Funding

### Sponsor



### Mission Area



1,736 Professional Technical Staff  
 1,048 Support Personnel  
 396 Technical Support  
 573 Subcontractors

3,753 Total Employees



Lincoln Space Surveillance Complex, Westford, Massachusetts



Reagan Test Site, Kwajalein Atoll, Marshall Islands